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WILLIAM-STREET, MAY 25th, 1859.

EXPERIMENTAL RESEARCHES

CONCERNING THE

PHILOSOPHY

OF

PERMANENT COLOURS;

AND THE

BEST MEANS OF PRODUCING THEM,

BY

DYEING, CALICO PRINTING, &c.

BY

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"Cet art (de la teinture) est un des plus utiles et des plus merveil-
"leux qu'on connoisse; & si *quelque un peut inspirer un noble orgueil à*
"*l'homme, c'est celui là:* non seulment il a procuré le moyen de suivre
"et d'imiter la nature dans la richesse & l'eclat des couleurs; mais
"il paroit l'avoir surpassé en donnant plus d'éclat, plus de fixité & plus
"de solidité aux couleurs fugaces & passageres dont elle a revetu
"tous les corps qui composent ce globe."

CHAPTAL, *Elémens de Chimie*, tom. iii. p. 185.

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EXPLANATION OF TERMS.

As many of those, for whose benefit this Work is intended, may not have been conversant with the new Chemical Nomenclature, I have thought it proper to insert the following explanations of some of the terms which will occur in the following pages: viz.

Acetates	Salts formed by the pure acetic acid with different bases.
Acetate of Copper	Copper in combination with acetic acid.
Acetate of Iron	Iron in union with acetic acid.
Acetic Acid	Strong dephlegmated acid of vinegar.
Acetous Acid	Undephlegmated acid of vinegar.
Adjective Colours, or Colouring Matters	Those which acquire their lustre and permanency by being adjected or applied upon a suitable basis.
Alumina, or Alumine	The pure argillaceous earth of alum.
Ammonia	Caustic volatile alkali.
Ammoniates	Combinations of ammonia with different bases.
Arseniates	Salts formed by the acid of arsenic with different bases.
Azote or Azotic Gas	The phlogisticated air of Priestley and others, the basis of nitric acid, and therefore called nitrogene.
Caloric	The matter or cause of heat.
Carbonates	Combinations of carbonic acid with different bases.
Carbonate of Lime	Lime united to Carbonic acid—Chalk.
Carbonate of Potash	Fixed vegetable alkali united to carbonic acid.
Carbonate of Soda	Mineral alkali united to carbonic acid.

Carbone, or Carbon	Pure charcoal, or its basis.
Carbonic Acid	Oxygene united to carbone, commonly called fixed air.
Citrates	Salts formed by citric acid with different bases.
Citric Acid	The pure acid of lemons.
Fluates	Salts formed by fluoric acid with different bases.
Fluoric Acid	That which is obtained from Fluor spar.
Hydrogene Gas	Inflammable air.
Muriates	Salts formed by muriatic acid with different bases.
Muriatic Acid	The acid of sea-salt, or common salt—Marine acid.
Muriate of Ammonia	Muriatic acid united to ammonia.
Muriate of Silver,	Muriatic acid combined with silver.
Muriate of Soda.	Muriatic acid united to soda—common or sea-salt,
Muriate of Tin,	Muriatic acid combined with tin.
Murio-Nitrates	Salts formed by muriatic and nitric acids with different bases, the muriatic being in the greater proportion.
Murio-Sulphates	Salts formed by muriatic and sulphuric acids with different bases, the muriatic being in the greater proportion.
Murio-Sulphate of Tin	Tin dissolved by muriatic and sulphuric acids.
Murio-Tartrites	Salts formed by muriatic and tartaric acids with the different bases, the muriatic being in the greater proportion.
Murio Tartrite of Tin	Tin dissolved by muriatic and tartaric acids.
Nitrates	Salts formed by nitric acid with different bases.
Nitrate of Alumine	Alumine combined with nitric acid.
Nitrate of Copper	Copper united to nitric acid.

Nitrate of Iron	Iron in union with nitric acid.
Nitrate of Lead	Lead combined with nitric acid.
Nitrate of Potash	Nitre, or saltpetre.
Nitrate of Silver	Silver in union with nitric acid.
Nitric Acid	Colourless acid of nitre, or aquafortis, in which the basis is saturated with oxygene.
Nitrogene	The basis of the nitric acid.
Nitrous Acid	Red or smoking spirit of nitre, in which the nitrogene is in excess, or not fully saturated with oxygene.
Nitro-Muriates	Salts formed by nitric and muriatic acids with different bases, the nitric being in the greater proportion.
Nitro-Muriate of Gold	A solution of that metal by nitro-muriatic acid, formerly called aqua regia.
Nitro-Muriate of Tin	A solution of that metal by nitric and muriatic acids, called *spirit*, by scarlet dyers.
Oxides (metallic)	Metals in union with oxygene, formerly called calces.
Oxygene	The basis of pure or vital air, or the aerial acidifying principle.
Oxymuriatic Acid, or Chlorine of Davy	The dephlogisticated marine (or muriatic) acid of Scheele, supposed by Berthollet to be muriatic acid combined with oxygene.
Phosphates	Salts formed by phosphoric acid with different bases.
Phosphate of Tin	A combination of that metal with phosphoric acid.
Potass, or Potash	Caustic vegetable alkali.
Prussic Acid	The colouring matter of Prussian blue.
Prussiates	Combinations of the Prussian colouring matter with different bases.

Pyroligneous Acid	The empyreumatic acid obtained by distillation from wood, &c.
Pyrolignites	Combinations of the Pyroligneous acid with different bases.
Soda	One of the fixed alkalies in a caustic state—the basis of common or sea-salt.
Substantive Colouring Matter	That which requires no basis or mordant to give it lustre and permanency.
Sulphates, or Sulfates	Salts formed by sulphuric, or sulfuric, acid with different bases.
Sulphate of Alumine	Common alum.
Sulphate of Copper	A combination of that metal with sulphuric acid—blue vitriol.
Sulphate of Indigo	A solution of Indigo by sulphuric acid.
Sulphate of Iron	A combination of that metal with iron, called green vitriol or copperas.
Sulphate of Zinc	A combination of zinc with sulphuric acid.
Sulphure, or Sulphuret of Antimony	A combination of that metal with sulphur—crude antimony.
Tannin	Vegetable matter by which skins are tanned or changed to leather.
Tartrites	Combinations of tartaric acid with different bases.
Tartrite of Alumine	Tartaric acid united to the earth of alum.
Tartrite of Tin	Tartaric acid in union with tin.

INTRODUCTION,

CONCERNING THE ORIGIN AND PROGRESS OF DYEING AND CALICO PRINTING.

THE Great Author of Nature having allotted and employed colours, to distinguish and adorn the various productions of his power, wisdom, and goodness, has also endowed some animals, and particularly man, not only with perceptions of the differences of colours, but also of the beauty arising from them, and their various combinations: and, in consequence of these perceptions, mankind, even in the rudest states of human existence, have been disposed to admire and desire ornaments, depending on gaudy and varied colours; which, in the state of naked savages, they have generally applied to their skins, and afterwards to their garments, when they had approached so far towards civilization, as to manufacture and wear clothing.* From these

* A confirmation of this observation may be found in the 1st chapter of the 22d book of Pliny's Natural History, in these words: "Equidem & formæ gratia ritusque perpetui, in cor-

motives, and the rude trials induced by them, even in remote ages, the arts of dyeing and calico printing undoubtedly originated.

It will appear in the following chapters, that colouring matters are of two very distinct classes; one, which requires no basis, or *mediating* substance, to fix it upon other objects, and which I have, therefore, denominated *substantive* colouring matter; and the other, whose durability* depends chiefly, if not exclusively, upon the interposition of some basis, and which, for that reason, I have called *adjective* colouring matter; and as dyes of the latter class, by being the most numerous, would naturally present themselves in the greatest abundance, and be applied without any means to render them

poribus suis aliquas exterarum gentium uti herbis quibusdam, adverto animum. Illiunt certè aliis aliæ faciem in populis barbarorum fœminæ maresque etiam apud Dacos & Sarmatas corpora sua inscribunt. Simile plantagini glastum in Gallia vocatur: quo Brittanorum conjuges narusque toto corpore oblite; quibusdam in sacris et nudæ incedunt, Æthiopum colorem imitantes."

* This is not always completely true in regard to *wool,* which is capable of attracting some few of the *adjective* colouring matters, particularly those of madder, galium, and cochineal, so as thereby to acquire tints of some durability, *unassisted by any basis*; but the colours so obtained will be much less durable, and much more deficient in brightness, than they would have been if dyed upon a suitable basis. But, in regard to linen or cotton it may be observed, that they have no such attraction for *adjective* colouring matters, and are, therefore, incapable of being dyed by them, without the aid of a basis.

permanent,* (because it would require numerous trials, and a concurrence of many fortunate accidents, to discover the use of any such basis) we may reasonably conclude, that most of the stains or colours first applied to wool, linen, or cotton, would have been fugitive. This, doubtless, was true of those which the Gauls are said by Pliny to have dyed from herbs;* as it has been of those which, in later times, have been seen among the uncivilized inhabitants of recently discovered islands and countries: and we may, therefore, consider the discovery of these bases, (denominated mordants by the French) and especially that of *alum*, (which is of all others the most *generally useful* in fixing adjective colouring matters,) as being a most important event in the history of dyeing; though it is now impossible to ascertain either the time or place at which this discovery was made.

* "Transalpina Gallia *herbis* Tyrium atque conchylium tingit, omneisque alios colores: nec querit in profundis murices, seseque objiciendo escam, dum præripit, belluis marinis, intacta etiam ancoris scrutatur vada, ut inveniat per quod facilius matrona adultero placeat, corruptor insidietor nuptæ." Lib. xxii. c. 2.

Herodotus, indeed, as an extraordinary fact, mentions a people living on the borders of the Caspian sea, who, by bruising the leaves of a particular tree, and mixing them with water, obtained a colour, by which they afterwards painted upon their garments, the figures of animals, &c.; which figures water could not afterwards remove. Book Clio, c. c. iii.

Beckman, in the Gottingen Memoires, and more recently in the first volume of his History of Inventions, has endeavoured to maintain, that the alum of the ancients, *was not*, like that of the moderns, a combination of sulphuric (or vitriolic) acid, with that white argillaceous earth, now called *alumine*,* (or alumina,) but a combination of that acid with either iron or copper, or perhaps zinc, and constituting those substances which were afterwards, and, until very lately, called green, blue, and white *vitriols* ;† and in support of this his opinion, he alleges, that the Greek and Roman authors, particularly Dioscorides and Pliny, mention no other than *native*

* This is not a complete description of alum, which, in fact, is a *triple* salt, (as seems to have been first discovered by Margraaff), for the combination of sulphuric acid with alumine will not crystallize, without an addition of either potash or ammonia. According to Vauquelin, 100 grains of alum consist of 30.52 of acid, 10.50 of alumine, 10.40 of potash, and 48.58 of water.

† When the term of *vitriol* was first used is not known. Beckman could find it in no writer older than Albertus Magnus, who says, "Viride etiam quod a quibusdam *vitreo* leum vocatur." Agricola and Vossius conjecture, that it was suggested by the likeness of these crystallized sulphates, to glass; to which, indeed, Pliny had long before compared them, in the 12th chapter of his 34th book; where, after having described the manner in which the atramentum sutorium, (sulphate of iron,) was made to crystallize upon ropes suspended over water, which held iron in solution, so that one end of each was immersed therein, he says, "*vitrumque* esse creditur."

alum, as being then known; that alum crystallized like the modern, is but seldom produced spontaneously; and that no mention can be found in any ancient writer, of the existence of any alum work, excepting that in Spain, noticed by Pliny, and which had for its object the crystallization of a sulphate of either copper or iron. He alleges, moreover, that every thing stated by ancient writers concerning their alum, is applicable to the metallic sulphates, since called vitriols. But this *last* allegation at least, is not correct, as may be seen by recurring to Pliny's 35th book, chap. xv. intitled, "De sulphure, *alumine,** & generibus corum, &c." in which he says, there are many kinds of alum: "Plura et ejus genera:" that of these, the island of Cyprus affords two; one *white*, and the other black; and that though their colours do not differ so much, *their uses are very opposite;* the white alum being of the *greatest utility* for dyeing upon *wool, clear* and *light*, or bright, colours; as, on the contrary, the *black* is, for dyeing *brown* and *dark colours:* "in cypro candidum & nigrum, exigua coloris differentia, cum sit *usus magna;* quoniam inficiendis

* Beckman supposes that, excepting Columella, Pliny is the oldest writer, in whose works the term *alumen* has been found, and that its derivation is unknown. He then asks, whether it may not have come from Egypt, with the *best* sort of alum?

claro colore lanis candidum liquidum, que utilissimum est, contraque *fuscis* aut *obscuris* uigrum." He adds, that they were all obtained by natural exudations from the earth; in Spain, Egypt, Armenia, Macedonia, Pontus, and Africa; and in the islands of Sardinia, Melos, Lipara, and Strongyle; and that of all these the *best* simply is that which comes from Egypt, and next to this, that of Melos. He afterwards proceeds to notice, separately, five several sorts, mentioning the Greek names of four of them, viz. phormion, paraphoron, schistos, (called also trichitis and chalcitis) and strongyle. His last or fifth species was in great estimation, and called melinum, because it came from the island of Melos; and he finally observes, that the different kinds of alum were all possessed of an astringent property, which had obtained for them their common Greek appellation, (στυπτηρια.)

That some of the several matters here mentioned by Pliny, under the general name of alum, consisted principally of iron, must be admitted, because, in addition to other reasons, he intimates that *two* of them produced a black colour with galls, and the peels of the pomegranate; and there are grounds also for believing, that one of them was a sulphate of copper. But I can discover no sufficient reason in this, or in any other part of his work, for believing, that Pliny did not also, under the name of alum, include a *sulphate of alumine*, not, perhaps,

crystallized like our alum ;* but in such a state of purity, especially in regard to iron, as would enable it to produce the *clear* and *lively* colours for which Pliny states one of his alums to have been highy useful; and which the sulphates of iron and copper, would not have produced ; nor that of zinc, (were it even certain that the ancients had ever employed it for dyeing,) unless, (which is not credible,) they possessed it in a state of much greater exemption from iron, than we find it even at this time.

The single fact of their (I mean the Greeks and Romans) having been able, long before Pliny wrote, to dye from the *kermes*, that beautiful red, or *coccinean* colour, which afterwards took the name of *scarlet*, and obtained the highest degree of estimation, is alone sufficient to prove that they must have possessed alum in some degree of purity at least, since it is known and ad-

* According to Berthollet, there is a mine of alum at Solfatara, near Naples, which, in the form of a white earth, contains alum, formed by the action of the sulphureous acid disengaged by the heat of the volcano, upon the argillaceous matter evolved by it. There, the alum requires only to be dissolved and crystallized. From a mine like this, or its earth, the good effects which Pliny ascribes to the white alum of Cyprus might be readily obtained. The famous alum mines of Tolfa, near Civita-Vechia are still purer, according to the accounts of Monnet, Bergman, and Vauquelin, by each of whom they were analysed ; but *there* the mineral requires torrefaction.

mitted that for dyeing, they were wholly ignorant of the use of tin, the only other basis by which the colour in question could have been produced. Indeed, the kermes would have afforded nothing but a black dye with any preparation of iron; and nothing better than a dark brown with any preparation of copper.

Beckman says, (vol. i. p. 292 of his History of Inventions, translated by Johnston,) that "when our alum became known, it was considered as a species of the ancient; and as it was purer, and more proper to be used on most occasions, the name of alum was soon appropriated to *it* alone. The kinds of alum, however, known to the ancients, which were real vitriols, maintained a preference in medicine and for *dyeing black*." But much of this appears to me absolutely incredible, as persons who had been acquainted with the alum of the ancients, would not, when that of the moderns was made known to them, have considered it as a species of the ancient, unless there had been some *cause* for doing so; and they never could have supposed that there was cause to consider our sulphate of alumine was a species of the ancient alum, if the latter had been so *peculiarly* deserving of estimation for *dyeing black*; or if, at least, one kind of it had not been suited to dye the *very different colours* which the sulphate of alumine is *alone* able to produce. To the dyer, no two substances could have ap-

peared so opposite or dissimilar; and there were, therefore, no two substances which he would be so little disposed to confound; and to confound in a manner so extraordinary, as that of giving the old name of alum exclusively to a supposed *new and very different substance*, and inventing a *new* name (that of vitriol) for the metallic sulphates, which he (Beckman) supposes to have before exclusively borne the name of alum. There was *then*, nothing in the name which could afford any motive for this change, if we suppose with him, that it had for so many ages been appropriated exclusively to the sulphates of iron, copper, and zinc; and it would in that case have been much more natural and convenient, to have allowed the latter to retain the name by which they had been so long distinguished, and to have invented a *new* name for the supposed *new* production. The truth seems to be that, notwithstanding the ignorance of the barbarous ages, the inconvenience of calling substances possessing the most opposite properties, by one common name, had been generally felt; and that to obviate this inconvenience, the name *vitriol*, as distinguishing the metallic sulphates, had been gradually adopted, and that of alum had been appropriated exclusively to the (perhaps impure) sulphate of alumine; and that when this came to be introduced from Syria in a crystallized form, it obtained in Italy, (for reasons to be hereafter considered,)

the *additional* appellation of *rocca*, or roccha, to distinguish it from that which had before been in common use, and hence the French name of alun de roche, and the English, of rock, or roach alum.

Were it ascertained that the Greeks and Romans, at the times of Dioscorides and Pliny, were wholly unacquainted with crystallized sulphate of alumine, even in that which Beckman calls that *best sort*, brought from Egypt, I should think it highly probable, notwithstanding, that such alum existed and was then employed among the people of Hindostan and other parts of India; where, (as will appear by facts stated between pages 346 and 350 of this volume,) the arts of dyeing and calico-printing had been practised more than two thousand years ago, exactly in the same manner, and with the very same means, (particularly crystallized alum and acetate of iron,) which were found to be in common use among them, when the Portugueze first reached that part of Asia, by sailing round the Cape of Good Hope; and without which, the art of calico-printing could never have existed. It will also appear, that the Egyptians, before the time of Pliny, had practised this art of calico-printing, and had borrowed therewith some productions necessary for the exercise of it, from Hindostan;* and it may be

* Among these, (as is proved at p. 250, &c. of this volume) was that most wonderful production, *indigo*, which

presumed, that crystallized alum, which is even now sometimes imported from India to this

seems to have originated among the Hindoos. The people of other countries had, indeed, found out ways to communicate substantive blue colours from different plants, and particularly from woad, or the isatis tinctoria, Lin. but not to precipitate and collect the colouring matter in a dry solid form, like indigo. *This* the people of Hindostan had not only effected, but they had afterwards done *that* which must have been more difficult, they had discovered the means of *dissolving* indigo when so prepared, in ways the most suitable for applying and fixing its colour permanently on the substances to be dyed with it; which the Greeks and Romans do not appear to have ever performed, though they knew how to powder indigo, and apply it as a paint.

From the fifth volume of that extensive work, intituled, "Memoires concernants l'Histoire, les Sciences, les Arts, les Moeurs, &c. des Chinois," it appears that wool was never worn in China but as a substitute for fur, and that cotton and silk, being the only substances ever dyed by the inhabitants, received all their colours from vegetable tingent matters; that these colours were principally red, blue, violet, and what is called a woad colour; and that, under the three first dynasties, the business of dyeing was chiefly practised by the female part of each family, for its own particular use: and it, probably, continued to be practised without any thing like principle or science until near the end of the seventh century, when the Chinese, discarding their own, borrowed the arts and means of dyeing which were then in use among the Indians and Persians: and it is said, that alum and copperas, which the Chinese did not use before, were among the means so borrowed; a fact which renders it probable that there was little, if any thing, in the Chinese art of dyeing, of which the loss need now be regretted.

country,) and which has been in use *there* during so many centuries, that no means exist for ascertaining when its use began, would, from its indispensable necessity, have been carried thence with other dyeing drugs to Egypt; and to me it certainly does not seem improbable, that this was that sort of Egyptian alum, which Pliny mentions as being in greater estimation than any other. Beckman, indeed, says, p. 291, "it is well known that *real* alum is reckoned among the exports of Egypt at present; but, (he adds) I am acquainted with no author who mentions the place where it is found or made, or who has described the method of preparing it." Whether the Egyptians, after obtaining alum from India, had, by doing so, discovered the means of preparing it in their own country; or whether they continued to obtain it from India, or were afterwards supplied with it by the inhabitants of any of the intermediate countries, who might have acquired this knowledge from the Hindoos, I know not; but it seems evident that Egyptian alum, however it may have been obtained, had been long and far famed, since Herodotus (in a passage which Beckman has quoted from his second book, c. 180) relates, that when the people of Delphos solicited a contribution for re building their temple, which had been burnt, Amasis, king of Egypt, sent them a thousand talents of *alum.*

Beckman supposes that crystallized sulphate of

alumine, similar to our alum, was, undoubedly, first made in the East; and that it was not known in Europe before the end of the 12th century; and if this be true, it seems probable, that the knowledge of it, and of the methods of bringing it into a crystallized form, had gradually spread from Hindostan, through Persia, and the intermediate countries, to Syria, where it was made use of before the overthrow of the Greek empire; and whence it was confessedly brought to Italy in the 14th century.* Beckman has given us extracts from the writings of three respectable historians; viz. John Jovianus Pontanus, Peter Bizaro, and Augustin Justinian, who all relate, that about the year 1460, Bartholomew Perdix, (by some called Pernix) a Genoese merchant, who had become acquainted with the preparation of alum in Syria) when returning thence to Italy, happened, at the island of Ænaria, now called Ischia, or Hiscla, to observe large alum stones among the substances which had been thrown up, more than one hundred years before, in consequence of the eruption of a destructive volcano there; and that, having calcined some

* Beckman mentions alum works as existing near to Constantinople, in the 15th century; and also one of great celebrity in the neighbourhood of Smyrna; whence the Italians procured alum and other dyeing drugs. He also mentions an Italian treatise written by Francisco Balducci, about the middle of the 14th century, by which it appears that the Italians were then acquainted with no other than Turkish alum.

of these stones in a furnace, he extracted from them excellent alum. But these historians all assert, contrary to the supposition of Beckman, that he (Perdix), in doing this, *only* revived and brought *back to Italy* an art which had, with many others, been lost amidst the darkness which, during several centuries, prevailed over the western empire; which art he had himself learned at the city of *Rocca*, in Syria. Beckman says, he had at first supposed, that this city might have been Rocca, on the Euphrates; but he had afterwards thought it more likely to have been *Edessa*, sometimes called Rocha, &c. and also Roccha; and that, though the latter is considered as being in Mesopotamia, the supposed limits of Syria, might, at that time, have extended thus far. From this city of Rocca, Beckman supposes, with Lisbnitz and others, that the best crystallized alum obtained in Italy, the additional epithet of Rocca; while some persons, and among them Julius Cæsar Scaliger,* think it to have been derived from the Greek name of a rock, alum being obtained, by boiling, from stones; and it seems to have been this opinion which caused the appellation to be translated into Latin, by the words *alumen rupeum*, and into French by those of alum de Roche; and there are again some, who

* "Vulgo audis *alumen rochæ,* que Græca vox maximæ Europæ servit parti ad rupem significandum." Exotic. Exercitat. Francf. 1612. 8vo. p. 325.

imagine, that this name was suggested, and occasioned more immediately by the alum *rocks* of the famous *mines* at *Tolfa*, near Civita-Vechia, from which alum of the purest quality has been longer extracted than from any other mine now subsisting in Europe; and these were discovered by John de Castro, a few years after Perdix had begun to produce alum from the stones which he found at Ischia. Of this memorable discovery, which happened during the pontificate of Pius the Second, that pope has given a circumstantial account; for which see "Pii Secundi Comment. rerum memorab. quæ temp. suis contingerunt," &c. Francofurti 1614, fol. p. 185.*

The wealth which the pope obtained from the

* Beckman has extracted this account, of which the following are the principal parts, viz.

This John di Castro, "being fond of travelling, had resided some time at Constantinople, and acquired much wealth by dyeing cloth made in Italy, which was transported thither, and committed to his care, on account of the abundance of *alum* in that neighbourhood. Having by these means an opportunity of seeing daily the manner in which alum was made, and from what stones, or earth, it was extracted, he soon learned the art. When, by the will of God, that city was taken and plundered, about the year 1455, by Mahomet, II. Emperor of the Turks, he lost his whole property; but, happy to have escaped the sword of these cruel people, he returned to Italy, after the assumption of Pius II. to whom he was related, and from whom he obtained, as an indemnification for his losses, the office of commissary-general over all the revenues of the Apostolic Chamber, both within and without the city.

discovery and working of the mines at Tolfa, encouraged and produced similar undertakings in other parts of Italy, particularly at Volterra, in

While in this situation, he was traversing all the hills and mountains, searching the bowels of the earth; he at length found some *alum* stones in the neighbourhood of *Tolfa*; and having made experiments by calcining them, he obtained *alum*, and repairing to the Pontiff, said to him, 'I announce to you a victory over the Turk. He draws yearly from the Christians above three hundred thousand pieces of gold, paid to him for the alum with which we dye wool of different colours, because none is found here, but a little at the island of Hiscla, formerly called Ænaria, near Puteoli, and in the cave of Vulcan at Lipari, which having been exhausted by the Romans, is now almost destitute of that substance. I have, however, found seven hills, so abundant in it, that they would be almost sufficient to supply seven worlds. If you will send for workmen sufficient, and cause furnaces to be constructed, and the stones to be calcined, you may furnish alum to all Europe; and that gain which the Turks used to acquire by this article, being thrown into your hands, will be to him a double loss, &c.' These words of Castro appeared to the pontiff as the mere result of idle dreams. He, however, employed skilful people, who found that the stones really contained alum; but least some deception might have been practised, others were sent to the place where they had been found, who met with abundance of the like kind. Artists, who had been employed in the Turkish mines in Asia, were then brought from Genoa; and these, having closely examined the nature of the place, declared it to be similar to that of the Asiatic mountains, which produce alum; and, shedding tears for joy, they kneeled down three times, worshipping God, and praising his kindness in conferring so valuable a gift on our age. The stones were calcined, and produced *alum more beautiful than*

the district of Pisa, though their success was greatly obstructed by the obstacles which the pope contrived and employed against them, in order that he might monopolize all the benefits to be derived from the manufacture and sale of alum; of which he raised the price so exorbitantly, that alum procured from the Turks was found much cheaper than that of Tolfa, and,

*that of Asia, and superior in quality.** Some of it was sent to Venice and to Florence; and being tried, was found to answer beyond expectation. The Genoese first purchased a quantity of it, to the amount of twenty thousand pieces of gold; and Cosmo, of Medicis, for this article laid out afterwards seventy-five thousand. On account of this service, Pius thought Castro worthy of the highest honours, and of a statue, which was erected to him in his own country, with this inscription:—'To John di Castro, the inventor of alum;' and he received, besides, a certain share of the profit; immunities and a share also of the gain, were granted to the two brothers, Lords of Tolfa, in whose land the aluminous mineral had been found. This accession of wealth to the Church of Rome was made, by the divine blessing, under the Pontificate of Pius II.; and if it escape, as it ought, the hands of tyrants, and be prudently managed, it may increase; and afford no small assistance to the Roman pontiffs, in supporting the burthens of the Christian religion."

* This alum continues to be known under the name of *Roman* alum, and esteemed above all others; principally because it contains but about half as much *iron* as most other alums: the latter, however, may be rendered equally pure and valuable, by calcining, then dissolving, and afterwards recrystallizing them. Stahl, Newman, Pott, and other eminent Chemists considered *alumine* as a calcareous earth, and not as being an earth, which it is, *sui generis*, nearly related to clay, but differing from it.

therefore, employed. But to obviate this interference, the pope pretended to devote the revenue produced by his alum works to the defence of Christianity against the Turks, and menaced all who should act so unchristianly, as to purchase, or procure, alum from these infidels, with excommunication; which prohibitions were renewed by several of his successors.

It appears from Biringocci's Pyrotechn, p. 31, that the first alum work established *out* of Italy, subsequently to the discovery of those of Tolfa, was that of Almacaron, near Carthagena, in Spain; whence, as is stated in Guicardini's description of the Netherlands, large quantities of alum were brought to Antwerp, in the early part of the 16th century.

In England the first alum work was that of Gisborough, in Yorkshire, begun near the end of Queen Elizabeth's reign, upon lands belonging to Sir Thomas Chaloner, who secretly procured workmen from the alum works at Tolfa, no person in England then knowing how to produce it. This seduction of his workmen so enraged the pope, as we are told by Pennant, in his Tour to Scotland, that his holiness endeavoured to frighten and recall them, by curses, or anathemas, in the *very form left us by Ernulphus.*

The intimate and important connection of the history of alum with that of dyeing, has induced me to state these facts, which I have chiefly derived from Beckman's first volume;

though I have not thought it right to adopt some of his conclusions on this subject.

To discover by retrospection all the ways and means by which an art like that of dyeing has been improved from its earliest and most simple beginnings, in different parts of the world, must now be impossible; because, among some nations, it, undoubtedly, would have been considerably advanced, by fortunate accidents and instructive observations, long before they had learned to write histories and record facts; and, indeed, almost all the progress which had been made in dyeing, until within a few years, must have resulted from such causes; depending, as it does, for its principles upon chemistry, which was by much too defective to afford any considerable assistance, either to practical dyers, or speculative men, who might have wished to study and improve the art; and, therefore, it happened, as might have been expected, that the *practice* of dyeing had, by the fortuitous discoveries of great numbers of individuals employed in it, been carried so far before the *theory*, that the latter was as little capable of *explaining*, as it had been of *suggesting* the most beneficial effects produced by it; and this, probably, was at least one reason why dyeing was so much neglected among the philosophers of Greece and Rome, though they highly esteemed the arts of painting, sculpture, &c.

Notwithstanding the great importance of alum in dyeing, it is not probable that mankind, with

their natural disposition to admire gaudy colours, and seek personal distinctions, should have delayed the application even of adjective dyeing matters, to their clothing, until they had become acquainted with alum and its effects, in raising and fixing the colours afforded by these matters. Such an acquaintance would not, in the ordinary course of events, be acquired, until some progress had been made in civilization;* and there are many facts to prove that, in much ruder states of society, men have attempted to dye their clothing;† and as these attempts would have proved more successful upon *wool* than upon linen, or cotton, by reason of the greater *affinity* of the former to some adjective colouring matters, (as

* Clavigero, in his history of Mexico, pretends that the Mexicans used the earth of alum to produce certain colours: that, after grinding and dissolving the aluminous earth, which they called *tlalxocotl,* they boiled it in earthen vessels, and then, by distillation, extracted the alum pure, white and transparent; and that, before they hardened it entirely, they divided it in pieces to sell in the market. To a chemical reader this will sufficiently discover the ignorance of the historian in regard to the effect of distillation, &c. What foundation this account may have had in other respects I know not.

† Of the nature of these attempts, and the value of some at least of the colours produced by them, we may judge, by the mention which Pliny has made of a purple dyed for the clothing of inferior people among the Gauls, from "vaccinia;" by which either the ripe privet, or the whortle berries, are supposed to have been meant. See Lib. xvi. c. 18. He also mentions *violets* as being used to produce a purple.

lately noticed) we may conclude, that in climates which required clothes of wool, the dyeing of these would have been practised much earlier than that of linen or cotton.* And, accordingly,

* Uncivilized nations appear, in some instances at least, to have found means to increase this *affinity*, particularly by the use of vegetable acids. The savage tribes of North America, had long been accustomed to dye certain animal substances, such as hair, feathers, and porcupine quills of bright *red* and *yellow* colours, whilst they were wholly unacquainted with the use of alum; and having been informed, that the red, so dyed, was produced from the galium tinctorum, and the *acid* berries of the scarlet sumach, lately mentioned, I made trial of them upon broad cloth *without alum*, and produced a red colour inclining to the orange, of considerable brightness, which, being exposed with a red less inclining to the orange, which I had dyed also from the roots of galium tinctorum only; but upon broad cloth, prepared as usual with alum and tartar, I found, at the end of two months, that, though the latter had suffered least, the other with sumach berries was much better and more lasting than I had supposed it possible to produce without some basis. I have since been informed, that the acid juice of the crab apple is sometimes employed by the tribes in North America for the same purpose; and that Professor Woodhouse, of Philadelphia, supposes himself to have discovered alumine in the very acerb fruit of the diospyros virginiana, or persimmon tree, which, if this supposition be well founded, may be expected to produce still better effects as a mordant for dyeing, than either of the acids before mentioned; unless the latter, as some have supposed, should also contain alum. Indeed, Loureiro (tom. i. p. 315.) has described a tree, under the name of decadia *aluminosa*, of which he says the bark, and more especially the dried leaves, are in great use among

Pliny mentions *dyed linen* as having been seen for the *first* time, in the fleet with which Alexander the Great had navigated the river *Indus*, when his captains, in skirmishing with the Indians upon its banks, to their astonishment suddenly changed the ensigns of their vessels, and displayed flags of various colours wavering in the wind.† It must, however, be confessed that, according to Pliny's account, the dyeing even of woollen clothes had, at that time, made but little progress, at least in regard to the finer colours; for, in the eighth chapter of his twenty first book, after declaiming against the luxury of his cotemporaries, in wearing clothes dyed of colours which *emulated* those of the *finest natural flowers*, he observes, that none of these flowery colours ("flores") were in use during the life of Alexander the Great; though, says he, nobody doubts of their

the dyers of Cochinchina, to *exalt* and *fix* their colours. "Magni usus sunt infectoribus indigenis in tingendis telis quarum colores decocto illorum nitidé *exaltantur* & *firmantur*." This statement, joined to the specific name of *aluminenosa*, appears to indicate that the bark and leaves of this tree either contain *alumine*, or are thought capable of answering the purposes of alum as a mordant.

* "Tentatum est tingi *linum*, quoque & vestium insaniam accipere, in Alexandri Magni primum classibus, *Indo* amne navigantis, cum duces ejus et prefecti certamine quodam variassent insignia navium: stupueruntque littora, flatu versi coloria implente."

having been borrowed by the Romans from the Greeks; for how else, he asks, should the names which they still retain in Italy, have been all Grecian, "a Græcis tamen repertos quis dubitet; non aliter Italia usurpante nomina illorum?"

Probably, the companions of Alexander, when he invaded Persia and India, became acquainted with the rich dyes of those countries; and afterwards made some, at least, of them known to the Greeks, among whom, as well as among the Romans, the wearing of *undyed cloths*, (which Pliny has denominated "*panni nativi coloris*") had been immemorially practised by the great mass of people.* We are not, however, to understand that dyed clothes were not in much higher estimation than the undyed, as soon as they were made known, for this, undoubtedly, was the fact; but they were too costly to be used by any but the rich and great, or for the service of religion, or upon extraordinary occasions. See Exodus, chapters 26, 28, 38, and 39. See also Plutarch, de Iside and Osiride. c. 78, where he tells us, that the robes or sacred vestments of *Isis*, were of *various* colours; but those of *Osiris* were of *one bright* colour. Juno, Venus, and Proserpine, were by the

* As these undyed clothes often wanted cleaning, this operation gave employment to a description of people called *Fullones*, who were properly *scourers*, though the clothes would naturally be thickened or *fulled*, in some degree, whilst in their hands.

ancient poets commonly represented as being robed in purple; and we are told, in the 37th chapter of Genesis, that Jacob "loved Joseph more than *all* his children, because he was the son of his old age; and he made him a *coat of colours*:" a distinction which caused Joseph to be hated by his brothers; and afterwards to be sold by them, and carried into Egypt.

Of the substantive colours known in Greece, and at Rome, two, (highly deserving of our notice) were the celebrated purple obtained from the murex and buccinum, and the blue procured from indigoferous plants, particularly the woad, (glastum or isatis tinctoria): of these, and of their connection with the history of dyeing, most ample and interesting accounts will be found, in the 4th and 5th chapters of the first part of this work. Another plant, by the Romans called *fucus*, and which appears to have been no other than that species of lichen which is now called *orchall*, was in such general use among the latter, for dyeing a beautiful, though not durable purple, that the name of fucus, came at length to be often used as signifying generally *a dye*. Of this also a sufficient account will be found at p. 291 of this volume.

In regard to the adjective colouring matters for which alum or aluminous earths and other mordants were employed by the ancients, I must observe, that it seems difficult to give a complete

account of them: though we have reason to conclude, that the kermes (or coccus illicis) and madder (rubia) were by much the most important: of these also, and of their connection with the history of dyeing, sufficient accounts will be found in their proper places. To these may be added the roots of anchusa tinctoria, or alkanet, the genista tinctoria, or dyer's broom, (mentioned by Pliny, xvi. c. 18.) gall-nuts, pomegranate-peels, alder bark, the rinds of walnuts, the bark of the walnut tree, and the pods of the Egyptian acacia; but of the particular methods in which these were employed, or of the basis or mordants used with them, no information worthy of being here particularly noticed has been transmitted to us, either by Greek or Latin writers. And, indeed, almost all the knowledge which the Greeks and Romans had obtained from others, or acquired by their own industry, on this subject, appears to have been lost about the fifth century, when, as M. Berthollet has observed, scarce any traces of science or humanity were left in the western empire. A few sparks of the former did, indeed, remain in Italy, where they were in some degree rekindled, by occasional accessions of knowledge, and of Greek artists obtained from the East, in consequence of the crusades; and also, from the various importations made by the Venetians, of oriental productions and manufactures; which, by affording new materials, and new objects of imi-

tation, assisted in exciting and directing that industry which had so long been dormant in the west of Europe.

Italy may, therefore, be considered as the *cradle* in which a feeble remnant of the knowledge of dyeing, as exercised by the Greeks and Romans, was nourished and invigorated, so as, with the *new* dyeing drugs since obtained from India and America, (which will be hereafter noticed) and with the various subsequent acquisitions of chemical and other knowledge, to have attained a state of improvement, greatly exceeding all former expectation.

From Italy some knowledge of dyeing, limited as it was, spread itself gradually to France, Spain, and Flanders, whence King Edward the Third of England, procured *dyers;* and in 1472, a company of these artists was incorporated in London.

The Germans, as Bischoff informs us, were slow in acquiring and practising the art of dyeing; excepting only that of *black*, which was their dress or gala colour; and excepting *browns*, which were generally wore by the monks, and the common people.

In France a division was established at a very early period, between the dyers of *lasting* colours, who were denominated "teinturiers en *bon teint*," and the dyers of fugitive colours, or those "en petit teint;" and the former were prohibited from

using, or having in their possession, the dyeing drugs employed by the latter. A similar distinction was also established in Italy, as Bischoff states, on the authority of a French ordinance of Nov. 17th, 1383.

The first Italian account of the processes used in dyeing, as Bischoff, and after him Berthollet, have informed us, was published at Venice in 1429, under the title of "*Mariegola dell' Arte dei Tentori*," of which a second edition appeared in 1510. But the imperfections of this work, induced John Ventura Rosetta, overseer of the Arsenal at Venice, to undertake a work less defective; and the better to execute his undertaking, he travelled over different parts of Italy, and some other countries, to acquire information; from which he composed, and in 1548 published, under the assumed name of *Plictho*, a collection of descriptions of the operations of dyeing, as then practised, which Bischoff considers as the foundation and principal cause of many subsequent improvements in this art:* though Hellot has mentioned it as deserving but little notice.

Of the important changes, and rapid advance-

* The title of this work, was "Plictho dell' Arte dé tentori che insegna tenger panni, tele, banbasi, e sede si per l'arte magiore, come per la commune. Vinezia 1448, 4to." Or Plictho's Art of Dyeing, which teaches how to dye cloth, linen, cotton and silk, of durable, as well as false, or ordinary colours, &c.

ment, which were produced in dyeing after, and by the discovery of new and valuable colouring matters, and also of new bases or mordants, (particularly that of tin) sufficient accounts are given in the course of this work, and to these I must refer, to avoid improper repetitions.

The first or earliest book, which I have been able to discover in the English language, relating in any considerable degree to the art of dyeing, is a thin and small 4to. volume, (now before me) in black letter, intitled "A profitable Booke, declaring divers approved remedies to take out spots and stains, in silkes, velvets, linnen, and woollen clothes; with divers colours how to *die* velvets, and silkes, linnen, and woollen, fustian, and thread: also to dress leather and to colour felles."

"Taken out of Dutch, and Englished by L. M. Imprinted at London, by Thomas Purfoot, dwelling within the New Rents in S. Nicholas Shambles, 1605."

The instructions contained in this last volume, relate principally to the use of indigo, (which is

Berthollet has remarked, that there is no mention in this work, of either cochineal or indigo; whence he infers, that neither of these important drugs had then been employed for dyeing in Italy; an inference which, though probably just, seems extraordinary, considering the facts which will be found in the fifth chapter of the first part, and the third chapter of the second part of this work.

called *flora* or floray), woad, madder, (particularly the *crap*) Brasil wood, weld, safflower, gall-nuts and alder bark; once or twice kermes and lac are mentioned; but not cochineal. These instructions seem to be founded chiefly upon the practices of the dyers in Flanders, where the art at that time was making considerable progress; but as black was the colour in most general use, the receipts, if I may so call them, for producing it, are in number equal to almost all the others. After this, nothing seems to have been done in this country to inform or assist practical dyers, until the year 1662, when the Royal Society, then recently formed, at their meeting on the 30th of April, desired Mr. Haak to translate into the English language the work which, more than half a century before, had been published in Italy, under the name of Plictho; (though this has never been done) and, on the same day, Sir William Petty, one of its earliest and most active members, in consequence of a previous request from the Society, brought in "An Apparatus to the History of the Common Practices of Dyeing," which was afterwards printed in Dr. Spratt's History of the Royal Society, and seems to have been the first *original*, though summary account published in the English language, of the means and operations used by dyers.

Nearly two years afterwards, viz. March 30, 1664, the Hon. Robert Boyle presented to

the Royal Society his "Experiments and Considerations, touching Colours;" and, on the 10th of August following, it was ordered by the Society, "that the way of *fixing colours* should be recommended to Mr. Howard, Mr. Boyle, and Dr. Merritt." These, and especially the two first, were among the most distinguished members of the Society; but it does not appear that they were able to do any thing deserving of notice, in consequence of this recommendation. However, at a meeting of the Society on the 11th November, 1669, that very ingenious, active, and useful member, "Mr. Hooke, produced a piece "of calico, stained after the way contrived by "himself, which he was desired to prosecute in "other colours, besides those that appeared in "this piece," (Birch's History of the Royal Society, vol. ii. p. 401.) And, accordingly, on the 9th of the following month, "Mr. Hooke "produced another specimen of staining with "yellow, red, green, blue, and purple colours, "which, he said, would endure washing with "warm water and soap." But from this time it does not appear that any thing considerable was done, for nearly the space of a century, by men of science in this kingdom, towards improving the arts of dyeing and calico printing; they being, probably, discouraged by the difficulties which, from the very imperfect state of chemical knowledge, must have occurred, in every attempt

to improve upon what the dyers were able to perform, without any principle or theory.

In France, however, that great minister, Colbert, anxious to extend the commerce and manufactures of his country, turned his attention particularly to the art of dyeing, with a view to amend, as well as to obviate frauds in the practice; and calling to his assistance M. D'Albo, a set of regulations and directions were prepared and published at Paris, first in 1669, and afterwards in 1762, under the title of "Instruction générale pour la "Teinture des Laines et Manufactures de Laine "de toutes Nuances, et pour la Culture des "Drogues ou Ingrédients qu'on emploie." This, however, was not intended merely to inform, but, as a legislative act, to control the dyers in their operations. It continued the former division of them into two classes; the one, dyers "*en grand*," who were confined to the colours deemed lasting, while the dyers "*en petit teint*," were allowed only to give those which were considered as fugitive; the drugs to be employed in each branch being also particularly specified; and the dyers in each prohibited from using, or having in their possession, any of the drugs allotted to the other. Such restraints, though intended to prevent frauds, would have operated as checks upon future improvements, if the government had not, at the same time, encouraged useful discoveries in this art, first, by offering particular rewards, and after-

wards, by appointing those eminent chemists, Dufay, Hellot, Macquer, and Berthollet, in succession, to superintend officially, the practice of dyeing, in its several departments, and to cultivate those branches of chemical and other sciences, which were connected with the principles, or capable of amending the theory, of that art; and, considering the eminent benefits which have resulted from the labours of these men, there is cause to regret the want of such an appointment in this *great manufacturing and commercial nation.*

With Dufay's assistance, M. Colbert's "Instruction" was amended, or rather superseded by a new one, published under the administration of M. D'Orry, in 1737. He (Dufay) appears to have been the first who entertained just conceptions of one of the causes of the adhesion of colouring matters to stuffs when dyed; I mean that which depends on an affinity or attraction subsisting between such matters and the fibres or substance of the dyed stuffs. He clearly perceived that without this, cloth, while in the dyeing vessel, could only acquire a degree of colour *equal* to that of the dyeing liquor, by an *equal participation* of the colouring matter dissolved therein; whereas, in fact, the cloth is often seen to exhaust, *by attracting to itself* all the tingent particles of the dyeing liquor, so as to leave it as colourless as water. He also noticed the dif-

ference in the degrees of attraction, which different substances, as wool and cotton, exert upon the same colouring matters ; and which he found so great, that a skein of each having been in an equal degree subjected to the means and operations commonly employed for dyeing scarlet, the woollen yarn was found to be fully and permanently dyed of that colour, while the cotton retained all its former whiteness.* He appears, however, to have had no conception of the other and more important cause of the permanency of adjective colours, I mean that which arises from the *interposition* of a *suitable basis*, possessing a particular *attraction*, both for the colouring matter and for the dyed substance ; and thereby acting as a *bond of union between them:* nor did his successor, Hellot, ever approach nearer to the truth on this subject. He, (Hellot,) indeed, published an excellent practical treatise on the art of dyeing wool and woollen cloths, in which the several processes were very accurately described: but in reasoning upon the facts stated therein, he adopted, and suffered himself to be grossly misled by, a frivolous hypothesis, devoid of the least foundation in truth. He fancied that he could discover, in every dyeing process, some means

* Observations Physiques sur le Mélange de quelques Couleurs dans la Teinture. Mémoires de l'Académie Royale, &c. 1737.

by which sulphate of potash (then called vitriolated tartar) might be formed; and this neutral salt not being readily soluble by cold water, nor by air or light, he conceived the whole art of dyeing to consist in first dilating the pores of the substance to be dyed, so as to procure a copious admission of colouring matter, divided by a suitable preparation into atoms, and then wedging or fastening these atoms within the pores of the dyed substance, by the small particles or crystals of this difficultly soluble neutral salt. Upon this *mechanical* hypothesis, he supposed that alum became useful in dyeing, not by the pure clay or alumine which it contains, and which alone contributes to fix any colouring matter, but by furnishing (and only by furnishing) sulphuric or vitriolic acid, to assist in forming the sulphate of potash, which was to perform this important function of wedging or fastening the colouring atoms; though, if he had brought this visionary hypothesis to the test of experiment, as might have been easily done, he would have found, not only that no sulphate of potash existed, in many of the cases where he supposed it to produce such important effects, but also that, even if intentionally formed and employed for this purpose, it possessed no power whatever of fixing any colouring matter yet known. But though nothing could be more groundless than this theory, the learned in all countries appear to have been satis-

fied with it for a considerable length of time, it being always less troublesome to believe than to make experiments. The late celebrated Macquer, in a Memoir, printed among those of the Royal Academy of Sciences for 1749, mentioning Hellot and his hypothesis, says, "ce savant "chymiste est le premier qui ait porté le *flambeau* "de la physique, dans l'art obscur de la teinture, "& qui ait rassemblé et mis en ordre, suivant les "principles d'une théorie ingenieuse, les phéno-"menes et les opérations bizarres de cet art: "il a mis les chymistes à portée de voir clair, dans "ce cahos ténébreux." And afterwards, in the preface to his Treatise on dyeing Silk, published in 1763, he makes this observation, "ce seroit "ici le lieu d'expliquer la maniere dont les mor-"dants agissent dans la teinture, et de dévelop-"per la cause du bon et du faux teint; mais ces "objets ont été traités avec tant de sagacité par "M. Hellot, que je crois devoir y renvoyer le lec-"teur;" and even so lately as the year 1766, in an eulogium pronounced upon Hellot, in the Royal Academy of Sciences, and published with the Mémoires for that year; the Secretary, after explaining Hellot's hypothesis, says, "à l'aide de "cette théorie si lumineuse, on ne sera plus trompé "dans la pratique de cet art, que lors qu'on voudra bien l'être."

Before this time, viz. 174[illegible], Scheffer published a small work on dyeing, which Bergman after-

wards thought worthy of being republished, with notes written by himself. It related in a great degree to the application, for the benefit of the Swedish manufactures, of the indigenous dyeing plants of that kingdom; in search of which, Linnæus afterwards undertook his *Iter* Gothlandicum. Scheffer was thought to have made discoveries of considerable importance in dyeing, but not having been published, most of them were lost, as Bergman informs us.

Mr. Henry, of Manchester, has observed, that Mr. Keir, the ingenious translator of "Macquer's "Chemical Dictionary, appears to have been the "first who suspected that (in dyeing) the earth "of alum was precipitated, and in this form "attached to the material prepared or dyed;" and this idea, having being published, was adopted by Mr. Macquer, and farther extended in the last edition of his "Dictionnaire de Chymie" at the article "Teinture," where he seems to have formed just conceptions of the nature and uses of alum, and of different metallic solutions, as mordants, in dyeing.* This edition was published

* Berthollet considers Bergman, as being the first who ascribed the fixing of colours, by dyeing, to particular affinities; and I cannot now readily ascertain dates so accurately as to decide whether he did this previously to Mr. Keir's publication of the translation of Macquer's Dictionary.

Perhaps it may be allowable for me to observe, that, in

in the year 1778, and Mr. Macquer soon after announced a design of writing a general treatise on the art of dyeing, which his death, however, frustrated. Some time after Mr. Macquer's decease, Mr. Henry favoured the public with a very interesting paper, (in the third volume of the Memoirs of the Manchester Society,) "On the "Nature of Wool, Silk, and Cotton, as Objects "of the Art of Dyeing; on the various Prepa- "rations and Mordants requisite for these dif- "ferent Substances; and on the Nature and "Properties of Colouring Matter, &c." A paper replete with useful information and ingenious ideas, (particularly respecting the causes of the durability of what is called the Turkey red,) and which deservedly reflects great credit on the author's talents and acquirements. And in the year 1791, that most excellent chemist, M. Berthollet, who had been appointed by the government of France to succeed Mr. Macquer in superintending the arts connected with chemistry, and particularly dyeing, published a work of great merit, under the title of "Elémens de l'Art de

a communication which I made to the Royal Society in 1773, mentioned in the last chapter of this work, I distinctly ascribed the production of ink and the black dye to this *affinity* between iron and the colouring matter of galls, and so far, at least, I had anticipated both Kier and Bergman. The first publication by the latter, on this subject, was, I believe, in 1776.

la Teinture," in two volumes, which has been translated into English by Dr. Hamilton.*

Before the publication of M. Berthollet's work, I had collected most of the materials for this undertaking; and, though he has anticipated many things which I was prepared to mention, (some of which I shall notwithstanding mention in my own way,) this production afforded me great pleasure as well as profit; because the author's superior chemical knowledge has enabled him to take just views of many intricate parts of his subject, and to reason with great solidity, as well as sagacity, upon most of the operations of dyeing. He has, moreover, enabled me to abridge my own work, by referring, as I must do to his, for more ample information upon several topics, particularly those of fuel, the different acids, alum, the sulphates of iron, copper, and zinc, verdigrise, acetite of lead, the different alkalies, soap, sulphur, arsenic, and water, of all which he has treated so ably and fully as to leave but very little for me to add respecting any of them.

But though I have been preceded by authors of such distinguished ability as Mr. Henry and M. Berthollet, the new facts and observations

* Since the above was written in 1794, a new and *improved* edition of the "Elemens de l'Art de la Teinture" has been published by M. Berthollet, conjointly with his son (lately deceased) and all my quotations from the Elements, &c. are to be understood to have been made from this *new* edition, unless the contrary be stated.

which I here offer to my readers, will shew that I did not find the subject exhausted : And, indeed, it is so far inexhaustible, that it probably will afford ample employment for the greatest talents and industry during many generations.

In justice to that very eminent and respectable chemist, M. Chaptal, I ought to mention that his excellent work, intitled " Elemens de Chimie," (in three volumes,) contains many ingenious facts and observations relating to the causes of the production and changes of colours, as well as to several other subjects connected with dyeing : And to these he has since made considerable additions in his most valuable work intitled " Chymie appliquée aux Arts" in four volumes 8vo. which was published soon after he had, with great difficulty, obtained permission to resign his office of minister of the interior of France, and return to his early and favourite pursuits.

M. Vitalis, of Rouen, has also recently published a small but useful work, intitled, Manuel du Teinturier sur fil & sur coton filé.

Some other works deserving of notice have also, within a few years, been published on this subject, particularly a French translation of that of Scheffer, with notes, by the celebrated Bergman; another by Pœrner, which has been translated into French from the German, and published with notes by Desmarets and Berthollot ; and a third by Dambourney ;

but neither of these has done much towards improving the theory of dyeing. That of Pœrner contains an account of many experiments made by the author, with different dyeing drugs; but, unfortunately, his reasonings upon them, and upon every part of the subject, are highly defective. Dambourney (a respectable merchant) was possessed of no chemical science, and he has done little more than give an account of the trials which he made with a considerable number of vegetable matters; few of which are likely to be ever much, if in any degree, employed by dyers.

Calico printing, though practised for many ages in some parts of Asia, seems not to have been seriously attempted in Europe, until the 18th century; and its progress, as well as introduction, were, for a considerable time, chiefly the result of British ingenuity and industry. Of their effects, some account will be given at p. 341 et seq. of this volume; and I shall only add here, that, about the year 1750, it was computed that fifty thousand pieces of linen and calico were annually printed in Great Britain, and chiefly in the neighbourhood of London; though, at that time, there was no calico printing in France, and the French government, to favour their silk manufactures, had prohibited, under severe penalties, the wearing of chintzes, and printed linens and cottons. In 1759, however, these prohibitions were annulled.

Eminent writers have derived the arts of dyeing and calico printing from a considerable degree of perfection, which they suppose chemistry to have somewhere attained in remote ages, though afterwards lost; and they imagine that particular processes of the art were preserved after the principles on which it was founded had been forgotten.* I am not able, however, to perceive any sufficient ground for these opinions. In fact, there is no good reason to believe, that chemistry ever had made any such progress among the ancients, or that they ever were so much engaged in the pursuit of knowledge by *experiment*, as would have been necessary for the acquisition of but a moderate portion of chemical science.† Even the operations of calico printing, as practised by the people of India, and which, above all others, have been considered as the result of an improved state of chemistry, are, in many respects, highly inconvenient, and incumbered with useless parts, which a little chemical knowledge would have taught them to reject, as, in-

* See Mr. Henry's paper in the third volume of the Memoirs of the Manchester Society. Also Hist. and Memoires de l'Acad. R. des Sciences, &c. 1750, and 1766.

† Pliny observes, that dyeing had never been considered as a liberal art; and he alleges this as an excuse for not giving a *rationale* of it. Lib. xxii. c. 2. But this was a mere excuse, because no degree of science then in the world could have enabled him to do so.

deed, they were rejected by the people of Europe, very soon after calico printing began to be practised here, though it began and was continued for some time with very little aid from chemical science. And, considering how far many of the operations of dyeing and calico printing have been carried towards perfection, unassisted by principles, we may say of this art, or, until very lately, might have said what Lord Bacon says of music, that "the practice has been well pursued, and in good variety, but the theory weakly; especially as to assigning the causes of the practice." Bacon's Works, by Mallet, vol. iii. p. 29.

But though the observations of many individuals, occupied with the means and operations of dyeing, through a long succession of ages in different countries, joined to very important *accidental* discoveries occurring from time to time, have produced great improvements in this art, with very little help from theory, we are not to infer that a knowledge of its true principles, and of the causes which operate in producing its various effects, will not prove useful in the highest degree; for, (as Mr. Henry has well observed) "though long experience may establish a number of facts, yet, if the rationale of the manner by which they are produced be not understood, misapplications are liable to be made; similar practices are pursued where the cases differ essentially; and improvements are attempted at

hazard, and often on false principles." And in confirmation of these truths, perhaps I cannot better conclude this Introduction, than by adding the following quotation from the History and Memoirs of the Royal Academy of Sciences at Paris, for the year 1761. *viz.*

" *La description des arts, faite avec une exactitude éclairée, depouillée de toutes les pratiques inutiles, que l'ignorance toujours mysterieuse y accumule sans cesse, & reduite* aux principes constans de la saine theorie, *est peutétre, le moyen le plus propre à hâter leur perfection, et à rendre plus abondantes* ces sources de biens & de commodités, que l'être suprème a voulû que les hommes dûssent à leur travail, et à leur industrie."

ERRATA.

The reader is desired to correct the following more considerable errors of the press, viz.

VOL. I.

Page 127, line 2 of the note, for "capha" read "bapha."
—— 255, — 1, for "besehryving" read "beschryving."
—— 256, — 10, for "historic" read "histoire."
—— 400, — 11, for "1806 read "1306."
—— 519, — 10, for "prts" read "parts."

VOL. II.

Page 60, for "Chap. II." read "Chap VI."
—— 148, at bottom, add the following line omitted, viz. "nary means for precipitating it, &c."
—— 278, line 1, for "Majrt'h" read "Manjit'h."
—— 284, — 18, for "Cocurdoux," read "Cœurdoux."
—— 286, — 6, for "Rabee" read "Rabec."
—— 398, — 13 of note, for "Morreau" read "Monnet."
—— 410, — 23, for "chebula terminalia" read "terminalia chebula."

CONTENTS OF VOL. I.

EXPERIMENTAL RESEARCHES
CONCERNING THE PHILOSOPHY OF
PERMANENT COLOURS.

PART I.

CHAPTER I.

Of the permanent Colours of Natural Bodies.

"Ceux qui exigent qu'on leur donne la raison d'un *effet* "*general*, ne connoissent, ni l'etendue de la nature, ni "les limites de l'esprit humain." M. DE BUFFON.

THE subject of this chapter was covered with darkness until the immortal Newton threw light upon it, by *dissecting*, if I may so express myself, the *matter* of *light* itself. By his Experiments we have been taught, that "the light of the sun consists of rays differently *refrangible*;" and that, when separated by the prism, in consequence of their different degrees of refrangibility, they afford all the various shades of colour, running gradually into each other, according to their particular degrees of refrangibility; the violet being most refracted; the indigo next; then the blue, green, yellow, orange, and red, which last is of all others, the least refracted; that the same rays also differ in degrees of reflexibility, according to their degrees of refrangibility.

That the proper colour of homogeneal light,

depending on its particular degrees of refrangibility, cannot be changed by reflections or refractions ; and " if the sun's light consisted of but one sort of rays, there would be but one colour in the whole world," nor the possibility of producing any new colour by reflections and refractions ; and, therefore, " that the variety of colours depends upon the composition of light."

That " colours, *in an object*, are nothing but a disposition to reflect this or that sort of rays, more copiously than the rest ; *in the rays*, they are nothing but their dispositions to propagate this or that motion into the sensorium ; and *in the sensorium*, they are sensations of those motions, under the *forms of colours*."

That " colours may be produced by composition, which shall be like to the colours of homogeneal light, as to the *appearance of colour*, but not as to the immutability of colour, and constitution of light ; and those colours, by how much they are more compounded, by so much are they less full and intense ; and by too much composition they may be diluted and weakened, till they cease, and the mixture becomes grey. There may be also colours produced by composition, which are not fully like any of the colours of homegeneal light." " For a mixture of homogeneal red and yellow, compounds an orange, like, in appearance of colour, to that orange, which, in the series of unmixed prismatic

colours, lies between them; but the light of one orange is homogeneal as to the refrangibility, and that of the other is heterogeneal; and the colour of the one, if viewed through a prism, remains unchanged; that of the other is changed, and resolved into its component colours, red and yellow. And after the same manner other neighbouring homogeneal colours may compound new colours, &c." And if to a colour so compounded, other colours be added in sufficient quantities, they will gradually overcome the first, and produce "whiteness, or some other colour." "So if to the colour of any homogeneal light, the sun's white light, composed of all sorts of rays, be added, that colour will not vanish or change its species, but be diluted; and by adding more and more white, it will be diluted more and more, perpetually." "Lastly, if red and violet be mingled, there will be generated, according to their various proportions, various purples, such as are not like, in appearance, to the colour of any homogeneal light; and of these purples, mixed with yellow and blue, may be made other new colours." "That whiteness, and all grey colours between white and black, may be compounded of colours, and the whiteness of the sun's light, is compounded of all the primary colours mixed in due proportion." To illustrate this, he produced *whiteness,* first by a mixture or re-union of the seve-

ral prismatic colours, and then, as he asserts, by mixtures of differently-coloured substances, in due proportions.*

Each particular colour being, therefore, a property of that particular sort of ray which produces the perception thereof, Sir Isaac Newton concludes, that the permanent colours of natural bodies arise from hence, that some of them "reflect some sorts of rays, others other sorts, more copiously than the rest. 'Minium reflects the least refrangible, or red making rays most copiously, and thence appears red. Violets reflect the most refrangible, most copiously, and thence have their colour, and so of other bodies; and, "whilst bodies become coloured, by reflecting or transmitting this or that sort of rays more copiously than the rest, it is to be conceived that they stop and stifle in themselves, the rays which they do not reflect."

Sir Isaac Newton's demonstrations and illustrations of this doctrine may be seen at large in the *first* Book of his Optics, to which I refer, without intending to propose any objection thereto. It may, indeed, be liable to

* This last assertion appears incredible, unless the coloured substances were *all transparent*. A painter, I am confident, would never produce *white* from any or all of the several opaque colours, in whatever proportions they might be mixed; and the Dyer who should, in the usual ways, apply them to a piece of white cloth, would soon find it become *black*.

several; but as these, even if well founded, would not affect my *ultimate* conclusions, I shall *thus far* adhere to the Doctrine under consideration.

Sir Isaac Newton's second Book, however, contains matter to which I cannot assent. He begins it with "Observations concerning the reflections, refractions, and colours of thin transparent bodies;" and mentions what had been observed by others, "that transparent substances, as glass, water, air, &c. when made very thin by being blown into bubbles, or otherwise formed into plates, do exhibit various colours, according to their various thinness; although at a greater thickness they appear very clear and colourless." And though he considers these colours as "of *a more difficult consideration*," yet as "they may conduce to farther discoveries for completing the theory of light, *especially as to the constitution of the parts of natural bodies, on which their colours or transparency depend*," he delivers his own observations on this subject: Of these, the principal was made, by taking "two object glasses, the one a plano-convex, for a fourteen-foot telescope, and the other a large double convex, for one of about fifty foot; and upon this, laying the other with its plane side downwards, I pressed them slowly together, says he, to make the colours successively emerge in the middle of the circles, and then slowly

lifted the upper glass from the lower, to make them successively vanish again in the same place. The colour which, by pressing the glasses together, emerged last, in the middle of the other colours, would, upon its first appearance, look like a circle of a colour, almost uniform from the circumference to the centre; and by compressing the glasses still more, grow continually broader, until a new colour emerged in its centre, and thereby it became a ring, encompassing that new colour; and by compressing the glasses still more, the diameter of this ring would increase, and the breadth of its orbit, or perimeter, decrease, until another new colour emerged in the centre of the last; and so on, until a third, a fourth, a fifth, and other following new colours successively emerged there, and became rings encompassing the innermost colour; the last of which was the black spot: And, on the contrary, by lifting up the upper glass from the lower, the diameter of the rings would decrease, and the breadth of their orbit increase, until their colours reached successively to the centre; and then they being of a considerable breadth, I could more easily discern and distinguish their species than before." And these he found to be in succession from the black central spot as follows, viz. first, blue, white, yellow, and red; then in the next circuit or order, immediately encompassing these, were

violet, blue, green, yellow, and red; in the third circuit or order were purple, blue, green, yellow, and red; after this succeeded in the fourth circuit, green and red; then the fifth of greenish blue and red; next the sixth, of greenish blue and pale red; and lastly, the seventh, of greennish blue and reddish white: but the colours in the last three circuits he describes as having been very indistinct, and ending in perfect whiteness.

"By looking through the two object glasses;" continues he, "I found that the interjacent air exhibited rings of colours, as well by transmitting light, as by reflecting it. The central spot was now *white*, and from it the orders of the colours were yellowish red; black, violet, blue, white, yellow, red; violet, blue, green, yellow, red, &c. But these colours were very faint and dilute, unless when the light was trajected very obliquely through the glasses. Comparing the coloured rings made by reflexion, with those made by the transmission of light, I found," adds he, "that white was opposite to black, red to blue, yellow to violet, &c." And as rings of similar colours were observed in bubbles, "blown with water, first made tenacious by dissolving a little soap in it," Sir Isaac Newton endeavoured mathematically to ascertain the different comparative thicknesses of air, water, and glass, at which the several circuits or orders

of colours appeared as before mentioned, which he has noted in a table prepared for that purpose, and from which this remarkable fact appears, that *similar colours* in the different orders *occur, and are repeated over and over again at very great diversities of thickness;* a circumstance which in my humble opinion, *proves incontestably*, that though *thickness* might *be one*, it *could not be, as he supposes, the only cause of these repeated variations of colour.** It was, at that period, the fashion to ascribe *even chymical effects* to *mechanical causes:* alkalies were supposed to neutralize acids, as the blade of a sword is sheathed by its scabbard; and the most learned physician of his age, soon after, thought it proper to write a *Mechanical Account of Poisons.* We are not, therefore, to wonder that Newton himself should have been misled on this subject, since the whole amount of chymical knowledge in his time, had he possessed it, would, like an *ignis fatuus*, have only served to light

* Sir Isaac Newton seems to have foreseen this objection to his hypothesis, and to have endeavoured to obviate it, by supposing the existence of what he denominated different *orders* of colours; in each of which it was conceived that the red, orange, yellow, &c. required for their production very different thicknesses from those which produced the same colours in the other orders: this, however, was but a supposition, improbable in itself, and repugnant to a multitude of facts, which will be mentioned in the course of this work.

him astray; as in truth it seems, in some degree, to have done; for, after stating as a proposition, that "the transparent parts of bodies, according to their *several sizes*, reflect rays of one colour, and transmit those of another, on the same grounds that thin plates, or bubbles, do reflect those rays," he goes on to mention, "that, by mixing divers liquors, very odd and remarkable productions, and changes of colours, may be effected; of which no cause can be more obvious and rational, than that the saline corpuscles of one liquor, do variously act upon, and unite with, the tinging corpuscles of another, *so as to make them swell or shrink* (whereby not only their bulk, but their density also, may be changed), or to divide them into smaller corpuscles (whereby a coloured liquor may become transparent), or to make many of them associate into one cluster, whereby two transparent liquors may compose a coloured one:" and laying it down as a proposition, that "the *bigness* of the component parts of natural bodies, may be conjectured by their colours," he endeavours, among other things, to explain why the syrup of violets, "by acid liquors, turns red, and, by urinous and alkalizate, turns green;" and for this purpose, he supposes, that "it is the nature of acids to dissolve or attenuate, and of alcalies to precipitate or incrassate;" a supposition,

which, as acids and alkalies are *chymical agents,** is not true of either of them, in the sense in which Sir Isaac Newton appears to have understood it; though, in another sense, it is partly true and partly false of both; since both are capable of dissolving a great variety of substances, and when a substance is dissolved by either it will most commonly be decomposed and precipitated by the other: but certainly the effect of coagulating, or *incrassating*, which he ascribes to alkalies, is much more frequently produced by acids; though nothing like it is produced in any of the changes of colour, which they occasion to the syrup of violets. It must be also observed, that Sir Isaac Newton has himself admitted, that what he calls "fat, sulphureous, unctuous bodies," possess refractive powers "two or three times greater, in respect of their *densities*, than the refractive powers of other substances, in respect of their's;" an admission, which seems incompatible with the conclusion which he almost

* When acids "dissolve or attenuate," it is by combining and forming a new compound with the matter so dissolved or attenuated; and when alkalies, "precipitate or incrassate," they always produce decompositions, and new compounds, which are totally foreign to those mechanical effects by which, Sir Isaac Newton intended to explain the changes of colour in question.

immediately after draws, "that nothing more is requisite for producing all the colours of natural bodies, than the several sizes and densities of their parts."*

In thus extending and applying his conclusions, respecting the *transient* colours of pellucid plates and bubbles, to the *permanent colours of all natural bodies,* Sir Isaac Newton appears to

* Since my objections to this part of Sir Isaac Newton's doctrine were published, Dr. Young, in the first volume of his lectures on Natural Philosophy, p. 469, has delivered the following observations respecting the Newtonian theory of the colours of natural bodies, viz.

"Sir Isaac Newton supposes the colours of natural bodies in general, to be similar to these colours of their plates, and to be governed by the magnitude of their particles. If this opinion were universally true, we might always separate the colours of natural bodies by refraction into a number of different portions, with dark spaces intervening; for every part of a thin plate, which exhibits the appearance of colour, affords such a divided spectrum, when viewed through a prism. There are accordingly many natural colours in which such a separation may be observed; one of the most remarkable of them is that of blue glass, probably coloured with cobalt, which becomes divided into seven distinct portions. It seems, however, impossible to suppose the production of natural colours perfectly identical with that of the colours of thin plates, on account of the known minuteness of the particles of colouring bodies, unless the refractive density of their particles be at least 20 or 30 times as great as that of glass or water; which is indeed not at all improbable with respect to the ultimate atoms of bodies, but difficult to believe with respect to any of their arrangements constituting the diversities of material substances."

have been influenced solely by *analogy;* he having made no experiment, or observation which would justify this extension. But in the year 1765, Mr. Edward Hussey Delaval, F. R. S. endeavoured to supply this omission, by communicating some experiments, and observations, on the agreement between the specific gravities of the several metals, and their colours, when united to glass, as well as of their other preparations," in a letter to the Earl of Morton, then president of the Royal Society: a communication for which the Society bestowed on him the annual gold medal provided by Sir Godfrey Copley. And though Mr. Delaval, in this communication, " treats of the difference of *density*, and the *colours* produced by that cause," he, notwithstanding, considers these as connected with " the colours arising from a difference of the size of the colouring particles ;" since, " by separating the particles of a coloured substance, they are removed to a greater distance from each other, so as to occupy more space," and, therefore, the substance so affected, " must undergo *a diminution of its specific gravity, at the same* time that the size of its particles is lessened." And as Sir Isaac Newton had inferred, that the refractive and reflective powers of bodies, were nearly proportional to their densities, and that the least refrangible rays, require the greatest power to reflect them,

Mr. Delaval conceived, "that denser substances ought, by their greater reflective power, in like circumstances, to reflect the less refrangible rays; and that substances of less density, should reflect rays proportionably more refrangible, and thereby appear of several colours, in the order of their density." And, in support of this opinion, he undertook to "give instances of natural bodies, which differ from each other in density, though circumstanced alike in other respects;" and also differ "in colour, in the same order as they do in density; the densest being red, the next in density orange, yellow, &c.

"In such an inquiry," says he, "metallic bodies seem to demand our first and principal attention, as their specific gravities have been ascertained, by well-known and repeated experiments." Mr. Delaval, however, must doubtless have perceived, that metals, in their pure simple forms, could not suit his purpose of supporting and extending the doctrine of Sir Isaac Newton, in this respect; since platina, which is much the heaviest of all metals, and of all known substances, instead of being the *most red*, as upon this hypothesis it ought to have been, is white, like tin, the lightest of metals; and gold, the heaviest of metals after platina, is much father removed from the red colour than copper, which is so much lighter. And this is more remarkably the case of quicksilver, lead, &c. To

obviate so formidable a difficulty, he thought it expedient to premise, that, "as the *inflammable matter* in the entire metals, acts strongly on the rays of light, it is necessary to calcine, or divide them into extremely minute particles, in order to examine separately the action of the calx, or *fixed* matter, on the rays of light." But here, at the very threshold, Mr. Delaval is forced to suppose the presence of what he calls inflammable matter *acting strongly on the rays of light*, and thus producing or changing colours, by properties very different from those of density, and size or thickness of particles. I might here deny, as, in truth, I am very far from believing, the existence of any such matter in metals, which, according to the new and prevailing chymical doctrine, are simple substances, uncombined with any such matter as is here supposed. Admitting, however, for the sake of argument, that phlogiston, or inflammable matter, does exist in metals; it must be recollected, that their calcination is not a mere abstraction thereof; since there is no fact in chymistry better ascertained, than that every metal in its calcination unites with a considerable portion of vital air, or its basis, the oxygene* of the modern chymists, and which

* By oxygene is meant that substance which, combined with and rendered elastic by heat, or by heat and light, constitutes vital air; or what Dr. Priestley terms dephlogisticated

(only by variations of proportion) is capable of producing, with particular metals, (and with other substances), all the possible variations of colour. Of this, however, Mr. Delaval takes no account: indeed, when treating of the colours of Mercury, he expressly says, "I have not entered into the consideration of the air, which unites with mercurial colours during their exposure to fire; because it does not relate to *the greater or less division of their particles*, which is the immediate subject of my inquiry." So that,

air (first discovered by him in August 1774), the only fluid suited for respiration; the *pabulum vitæ*, without which the more perfect animals cannot live, even for a few minutes. But as the stimulant or exhilarating effects of this (vital) air would excite, and wear out, the powers of life too much and too rapidly, if it were inspired without mixture, the wise Author of Nature has presented it to us diluted with nearly four times as much of a different air not respirable by itself, and which is now denominated *azote*, or nitrogene. These two airs, with a very small portion of carbonic acid gas, or fixed air, and some accidental or extraneous matters, compose our common atmospheric air. The oxygene, combined with nitrogene, constitutes, according to their different proportions, either the nitrous or nitric acid; the same oxygene united to sulphur by combustion, produces either sulphureous or sulphuric (vitriolic) acid; and, with other bases, it seems to produce most of the other acids. With pure charcoal (carbone) it produces carbonic acid (or fixed air), and with inflammable air (hydrogene) it produces water. This explanation may be useful to readers not acquainted with the modern chymistry.

by his own statement, he has overlooked (because it did not suit his hypothesis) *the only thing worthy of notice on this subject*; since the oxyds or calces of Mercury, and, indeed, of all other metals, indisputably receive their various colours only by additions, greater or smaller, of that air which he professes to have disregarded; and which, as he declares, has no relation to the greater or lesser division of their particles; and we must therefore conclude, that the various colours assumed by these calces, under the circumstances in question, do not result from any such division.

But though Mr. Delaval inculcates the necessity of calcining metals, "in order to examine separately the action of their calces or fixed matter, on the rays of light," he does not adduce the colours which they assume when so calcined, as any evidence of the truth of his hypothesis; and, indeed, he might have perceived them to be absolutely incompatible with it, since the same oxyd, by different degrees of calcination, exhibits very great diversities of colour. But in order to obtain from several of the metals such colours as *suited* his purpose, he continued to melt them with what he was pleased to think "a quantity of the purest glass," and as they, when more or less calcined, and melted or united with a greater or less portion of glass, are capable each of giving several, and some of

giving all the colours, it could not be difficult for him to find out, and assign to each metal, as its proper colour, that which it ought to have, upon his supposition that the colours of metals depended on their respective densities. Thus, for example, iron highly calcined, or combined with a large portion of the basis of vital air, (oxygene,) gives a red colour to melted glass; and if the glass be continued in fusion, the (oxygene) will by degrees be separated, and in proportion to its separation, the colour of the glass will change to orange, yellow, green, blue, and white. And as blue is the colour which suits Mr. Delaval's purpose, he selects and assigns it as the proper colour of iron, and the degree of heat producing it, as the proper one for manifesting those which suits him to consider as the true colours of metals; though in fact he took no means to ascertain what this degree of heat really was; and the effect, or blue colour, would require very different degrees, according to the greater or lesser degree of calcination which the iron had previously undergone, or, in other words, according to the quantity of oxygene previously combined with it.

Where every thing is in this way assumed or supposed at pleasure, not only without evidence or probability, but often against both, it must have been easy for Mr. Delaval to give some plausibility to this fallacious hypothesis, though it

is absolutely incompatible with a multitude of facts.

Mr. Delaval has quoted, from Glauber's Prosperity of Germany (translated by Packe, 1689), some curious observations respecting the various colours produced by manganese; and he adds, as from his own knowledge, that " amongst the mineral substances none affords a greater variety of bright colours, especially when it is fused with nitre, or a fixed alkali;" of these he instances a yellow, produced by dissolving manganese in a weak spirit, together with a green, blue, purple, and red, produced by water poured on it; in the first instance cold, and in the others warm, then warmer, hot, and boiling; all which colours he ascribes to different degrees of solution, or attenuation, of the particles of manganese. But in truth this and other metallic calces or oxides, had he properly attended to their various changes of colour, might have shewn him both the fallacy of his own hypothesis, and the road to a better. Manganese is the oxide or calx of a metal which has so strong an attraction for the basis of vital air, that one of the most excellent of chymists, Berthollet, says, we may safely consider the whole of what exists in nature to be as in a state of oxidation, or combination with oxygene: when saturated therewith, I mean with the basis of vital air, it is black; and if it

be diluted or diffused in melted glass, it becomes purple, or red; and as the vital air diminishes by burning with the coaly impurities, (which it is employed to destroy,) in glass, it gradually loses its power of producing colours, and leaves the glass colourless; though its colours may be restored by nitre, or any thing affording pure air. The different solutions of manganese, mentioned by Glauber, and others, undergo their various changes of colour, in consequence of a gradual separation or diminution of their oxygene; and that this is what manganese possesses, and what it loses, in these operations, is well known to all who are acquainted with the later chymical discoveries. I have already noticed the various colours assumed by the oxides or calces of iron, when combined with different portions of the same air, or its basis, the oxygene, which are indeed so many and various, that I remember having been told by the late Mr. Wedgwood, that all the diversified colours applied to his pottery, were produced by the oxides of this single metal; which must have been all of very nearly the same specific gravity, and they were besides, in these cases, combined or melted with glass, the substance which Mr. Delaval thought proper to choose, as being of all others the best, for exhibiting what he was pleased to think the true colours of metals. In like manner the oxides

or calces of mercury, lead, copper, &c. assume each a variety of colours, by combinations with different portions of oxygene, without any thing like a correspondent variation of density, or of specific gravity in any of them. Of this Mr. Delaval appears to have been sensible, at least in the instance of lead, and he endeavours to obviate the evidence which it affords against his theory, by ascribing the various colours of that metal to its "imperfection," which he is pleased to *suppose*, without any, and against every, kind of proof and probability: and then he proceeds to say, " it is probable that, during the calcination, lead receives a small portion of *phlogiston*, as well as of air; for the affinity between the earth of this metal and inflammable matter is very great, as appears from the readiness with which its solutions and calces unite with phlogistic vapours. " The effect of such an union," he adds, " must probably be a change of colour from orange to red; for Sir Isaac Newton has shewn, that bodies reflect more strongly in proportion as they possess more phlogiston, and that the less refrangible colours require greater power to reflect them." Here we have another gratuitous and strange supposition of an accession or combination of phlogiston with lead in calcination: I say strange, because those of the adherents of phlogiston who yet continue to believe its existence in metals, have constantly

supposed that, in calcination, while they received air, they *lost, instead of gaining, inflammable matter.* But were this extravagant supposition to be admitted as a cause of the changes of colour in metals, how can it be reconciled to any hypothesis which makes their colours depend on their respective densities? Indeed, if the effects which Sir Isaac Newton supposes phlogiston to produce on colours were real, and if phlogiston existed in them, as he and Mr. Delaval imagined, it would be difficult to conceive why all metals are not red, or more inclined to redness, than their calces or oxides. But enough, perhaps too much, has been said, to refute Mr. Delaval's hypothesis, so far as it relates to the colours of metals. Unfortunately, however, for my readers, as well as for myself, he has thought proper, in a larger work,* published some time since, to extend the same hypothesis to the colours of animal and vegetable substances; and has endeavoured to confirm and illustrate Sir Isaac Newton's ideas on this subject, by a variety of experiments, which are represented as instances of changes of colour produced in these substances, by an increase or diminution in the sizes of their particles: I am, therefore, compelled reluctantly to extend my

* Experimental Enquiry into the Cause of the permanent Colours of opake Bodies. 4to.

own observations a little farther on this subject; and I must begin by complaining of a continuance of *gratuitous* and *fallacious suppositions*, similar to those which I have before had occasion to notice; for when, in operating upon, or with different matters, he professes either to increase or diminish the sizes of their particles, and *to do nothing more*, (to shew that the changes of colour produced in them, accord with the thicknesses stated in the table of Sir Isaac Newton,) instead of choosing and employing *mechanical* means, which alone are suited to produce these, and *only these effects*, he has recourse to mere *chymical* agents, whose action in the ways which he supposes, must have been always doubtful at least, though their powers of producing other, and very different effects from any supposed by him, is most certain. Mr. Delaval, however, adopting Sir Isaac Newton's supposition, that acids always attenuate, and alkalies always incrassate, prepared what he considered as a dissolving or attenuating liquor; which "consisted of water, with about an eightieth part of *aqua fortis*: and when he wanted to lessen the dissolving force of this liquor, instead of weakening it by the addition of water (which would certainly have been the most obvious and unexceptionable expedient), he chose to do it, as he says, by adding "a small quantity of a solution of potash, or some other alkaline liquor;"

and thereby produced a new composition, the effects of which must, in many cases, prove different from those of a mere diminution of the supposed dissolving power of the former liquor. And on the other hand, when he wanted to increase the force of his acid liquor, instead of doing it by a farther addition of aqua fortis (obviously the most proper expedient), he recurs to an addition of *oil of vitriol;* an acid possessing very different properties, and producing very different effects, on a great variety of substances, and particularly on colouring matters; of which I could allege hundreds of instances, but shall content myself with only mentioning, that the strongest and most concentrated oil of vitriol (used to dissolve indigo for dying the Saxon blue, &c.) does not destroy, or even weaken, its blue colour, though a diluted nitric acid, or aqua fortis, will wholly destroy it, and convert the indigo to a dirty brown mass, of no use whatever.

Having thus assumed, that acids attenuate, and do nothing but attenuate, the particles of colouring matter; that alkalies incrassate, and doing nothing but incrassate, the same particles; that by adding an alkali to his mixture of aqua fortis and water, he weakens, and only weakens, its attenuating force on one hand; and that on the other he increases, and only increases it, by an addition of vitriolic acid; he next provides

himself with so much of Sir Isaac Newton's table before mentioned as suits his purpose, by transcribing the different colours of the three first orders, and the different thicknesses of air, water, and glass, supposed to produce each of these colours, one after the other; and thus *equipped*, he proceeds to make experiments upon red infusions, of certain vegetables, and generally finds, that with his acid liquor, the colour continues *red;* that, with the addition of oil of vitriol, to attenuate farther, (as he supposes) it becomes yellow; and that if, instead of oil of vitriol, he adds an akali, to *incrassate*, it becomes a purple. Now it so happens, that though all the other colours are repeated in more than one order, purple is marked but once in Sir Isaac Newton's table, and then it is placed as the first colour of what he terms the third order; and if the red and yellow, from which the purple in question had proceeded, were supposed to be of the same order (as might be expected), then the production of this purple ought, upon Mr. Delaval's theory, to result not from incrassation, but from attenuation; since the particles of it are stated to be nearly one-third less in size, than the particles of the red, and nearly one-fourth smaller than those of the yellow of the same order: but such is the happy arrangement of this table, and of the several orders of colours, that, by supposing the red in

this instance to be the red of the second order, he finds a purple below it in the third, with *only one intervening colour*, and a yellow at *the same distance above;* and by these *leaps*, he reconciles the appearances to the theory. Indeed, as the second, or middle order in the table, contains all the different colours, and as, excepting one, they are all repeated in the first order, which is *above;* and also in the third, which is *below;* hardly any change of colour can happen, which may not be made to accord with Mr. Delaval's hypothesis, he being always allowed to suppose each original or primitive colour to belong to that order which may be most convenient for his purpose; though, in truth, the very admission of different orders or repetitions of the same colours, produced repeatedly by and at *different* thicknesses, or sizes, either of particles or plates of matter, is of itself a proof (as I have before observed) that such colours do not depend on any particular thickness of plates or size of particles.*

* When Mr. Delaval, on every occasion, allots each particular colour to some one order, exclusively of the rest, it would seem reasonable to expect, that he should justify this allotment by something besides his own convenience, and particularly that he should prove that the red, for instance, which he places in the second order, exceeds that of the first order, in the density and size of its particles, exactly in the same proportion as $18\frac{1}{3}$ exceeds 9; and that the red which he places

I am far from thinking that Mr. Delaval has always chosen the matters, most proper for fair experiments, or that the experiments themselves, even on his own principles, were well calculated to ascertain the truth. But such as they are, I can readily point out several, which, on his own improbable, or rather impossible supposition, of mechanical attenuation or incrassation, and nothing else, by chymical agents, cannot be reconciled to his theory, even by the assistance of Sir Isaac Newton's covenient table. The green leaves of the anil (indigofera) and glastrum, he says "being long steeped in water, their parts are *dissolved* into a blue substance, which is indigo and woad." Now the truth is,

in the third order, exceeds that of the second exactly in the proportion of 29 to $18\frac{1}{3}$: and that the other colours of the several orders, differ from each other likewise, according to the proportions stated to be *necessary* for their production, in the table which he has adopted from Sir Isaac Newton. Before this division of colours into orders, and the hypothesis connected with it, can be admitted to have any other than an imaginary foundation, it ought to be proved, that all the known reds, differ from each other in respect to the densities [and sizes of their particles, *exactly according to the before-mentioned proportions*; and so of the oranges, yellows, &c. since, in every case, the slightest deviation from the thickness or size of particles, stated as essential to the production of a particular colour, ought to occasion the appearance of that colour, which is next in the series above or below. But nothing like this is any where attempted, nor is there any thing accessible to human observation, which could in any degree justify the attempt.

that the blue arising from these vegetables is not the result of any *dissolution*, but of an absorption of pure air, during the fermentation which they undergo; and this colour does not manifest itself, until there is a beginning *aggregation* and *concretion* of its matter, into *larger* particles, which becoming *denser*, as well as *larger*, sink down to the bottom, leaving the water nearly colourless. So that here the change from green to *blue*, is manifestly accompanied with an increase, both in the size and density of the coloured particles, which is absolutely incompatible with Mr. Delaval's hypothesis; since, according to the table in question, every change of colour from green to blue is the effect of a *diminution*, not an *increase*, in the size and density of its particles. When the indigo itself (formed into dry masses) is to be dissolved for dying, by the combined action of *caustic* alkalies, and of particular chymical attractions, or vegetable ferments, the solution, though manifestly attended with a division or diminution of the coloured particles (as well as a loss of the air absorbed during the first process) becomes green, *contrary* to the table and hypothesis in question; and in this state, it is applied by the dyers to wool, and other substances, to be dyed; and these, when first taken out and exposed to the air, appear green; but by absorbing, and uniting with a portion of oxygene,

they immediately become blue, and in doing so, the divided particles again concrete into larger ones, as must be evident, among other proofs, from this, that the surface of the indigo liquor, on which the air has an immediate action, is from that cause always blue; and if we skim off this blue matter, (which is nothing but indigo revived) it will be found impossible to make it enter the pores of any substance, so as to dye a permanent colour therewith; because the particles having regained their proper portion of pure air, or its basis, are no longer sufficiently divided and dissolved for that purpose; so that in all these cases, the matter of indigo becomes more dense, and its particles larger, in passing from green, to the more refrangible colour, blue; and the contrary, in passing from blue to the less refrangible colour, green. And this is also the case, when the infusions of rhubarb, turmeric, &c. are made "to descend (as he expresses it) from yellow to orange and red," "by the addition of an alkali," which, whatever he may imagine to the contrary, *dissolves* these colouring matters more powerfully than any acid. Similar objections occur, in opposition to the instances which Mr. Delaval alleges, respecting "the changes of Colour which animal substances undergo." Among these, *e. g.* he observes, that cow's milk, boiled up with an alkali, changes from white to

yellow, orange, and red; and, as usual, he gratuitously supposes, that, in producing these changes, it acts by *incrassating*, or coagulating the milk; though if, contrary to all probability, alkalies were able to do this, we have no reason to conclude that such coagulation would render the milk either yellow, orange, or red, because no such colours appear when it really is coagulated by acids, &c. as in the making of curds and cheese. But surely it cannot be necessary for me, seriously to combat such chimeras any longer. The common sense and experience of mankind, if fairly consulted, will condemn and revolt at the idea, of making the colours of bodies depend on their weight, or the sizes of their particles; for it certainly never has been observed, that the heaviest substances were red, or the lightest violet-coloured, or that bodies equally heavy were all of the same colour. Different parcels of indigo, for instance, vary extremely as to specific gravity, without any variation of colour; a fact which is not only at variance with Mr. Delaval's hypothesis, but which renders it easy to find samples of indigo, of exactly the same specific gravity as the colouring matter of cochineal (exhibited in what is called *carmine*,) which of all colours is the farthest removed from that of indigo: and if Mr. Delaval should allege, that, though agreeing in weight, they differ as to the sizes of their

respective particles, let him correct this difference by the only means suited to do it, without doing more; I mean by simple mechanical division, or grinding. Let this be employed upon either of the substances in question, whose particles he may suppose too large, as long as he shall think proper, and let us then see whether he can thereby render the colour of indigo red, or that of cochineal blue or violet.

Should what I have said on this subject prove insufficient to convince any one of my readers, I only beg that he will follow me, with a mind open to conviction, through the various instances, which, for other purposes, I shall have occasion to state hereafter, of colours produced, or changed by means, and in ways that are wholly irreconcileable to the theory in question, and I persuade myself that his doubts and difficulties will be effectually removed, so far as they may relate to the truth or fallacy of Mr. Delaval's hypothesis, of which I mean hereafter to be silent, because I dislike even the appearance of contention; nor would I have so long detained my readers on this subject; but from a conviction of the truth of what I have written, and of the expediency of refuting an hypothesis, incompatible with a considerable part of what I am about to offer to the public; an hypothesis which the name and authority of Sir Isaac Newton had pre eminently sanctioned; and which

the learning and talents of Mr. Delaval had rendered so plausible, that it is, I believe, generally considered as true, in this and other countries.*

Having shewn, that the permanent colours of different objects, do not arise from their densities, or the sizes of their particles, it becomes me to state such facts and observations, as seem best suited to throw light upon this obscure and interesting subject.

Sir Isaac Newton having found that inflammable substances, possessed greater refractive powers than others, in proportion to their densities, says, in his second Book of Optics, that "it seems rational to attribute the refractive power of all bodies, chiefly, if not wholly, to the sulphureous parts with which they abound; for, adds he, it is probable that all bodies abound more or less with sulphurs;" a term by which he intended to distinguish inflammable matters generally. And this great man having also concluded, that the permanent colours of natural bodies, were analogous to the colours produced by the refractions of thin, colourless, transparent plates, &c. chymists were generally induced to make all colour depend on the principle of inflammability or phlogiston, which was supposed to exist in all metals, and many other sub-

* Such *was* the fact in 1794, when this was first published.

stances; and where the total want of inflammability was manifest, they *confounded this*, with the *matter* of heat and of light; to which they ascribed the power of *phlogisticating* other substances, and of thereby producing or changing their colours: a species of confusion suited only to cover and perpetuate ignorance; since every single colour is found to belong both to combustible and incombustible substances, and to neither exclusively. The *combustible* diamond, which Sir Isaac Newton conjectured to be "*an unctuous substance* coagulated," is found to be of almost all the different colours, whilst other gems, though of similar colours, are all *incombustible*. Combustible indigo, and incombustible smalt, are both blue; combustible vermillion and incombustible minium are both red; combustible gamboge, is yellow; and so are certain incombustible oxides of lead, iron, and mercury. But since the existence of phlogiston in metals, &c. has been denied by the pneumatic chymists, they have in most cases, attributed the origin and changes of colours, to the application or combination of different airs or gazes, and particularly oxygene in different proportions; and it has been supposed that these gazes, possessed considerable *refractive* powers, and were *thereby* enabled to produce effects on colours, like those which the followers of Stahl, had imputed to phlogiston: and M. Berthollet, in his recent work on the Elements

of Dying, intimates, that "many important observations still remain for those who would follow the steps of that great man (Sir Isaac Newton), and compare the *refracting* powers of the different gazes, and other substances, the constituent principles of which are now known."*

* Ten years after my first edition of this volume was published, M. Berthollet (assisted by his son, lately deceased, and too soon for the interests of science) favoured the public with an improved edition of the Elements de Teinture, in which (at page 33, of the first volume) he intimates, that it was his intention, by the words just quoted, to express some doubt of the correctness of this part of Sir Isaac Newton's doctrine; and he adds, "depuis lors Bancroft lui a opposé un grand nombre de faits. Nous nous servirons de ses differentes observations, dans la discussion que nous n'allons entreprendre, que dans la vue d'appeler sur cet objet interessant, l'attention de ceux qui peuvent suivre les traces de *Newton*." He then proceeds through nearly twenty pages to repeat the facts and arguments which I had employed on this subject, and to adduce other facts and arguments in their support, from all which he concludes, nearly as I had done, "qu'il ne faut point confondre les couleurs fugitives qui sont produites par la reflexion des lames, and qui suivent les loix determinées par Newton, avec les couleurs qui se conservent malgré les changemens de densité and d'épaisseur. Celles-ci nous paraissent tenir a des propriétés, ou l'affinité particuliere pour les différents rayons de la lumiere, a une influence qui resiste a celle des dimensions et de la densité; si nous examinons les faits, nous apercevons que l'oxigène condensé exerce un grand pouvoir dans cette espéce d'affinité: une proportion un peu plus on un peu moins grande, qui affecte d'une maniere insen-

Though it be true that the prism, and other transparent colourless substances, in different forms, shew us the different colours of the several rays of light, by *separating* them from each other, in consequence of their greater or lesser refrangibility, or disposition to be "turned out of their way, in passing out of one transparent body or medium into another," (which may depend upon differences in their sizes, densities, or velocities,) yet the *permanent* colours of different bodies, or substances, *are not*, as I believe, *produced by mere refraction*, and Sir Isaac Newton must have been misled by analogy when he extended his discoveries and conclusions respecting the transient colours resulting from the refractions of light, by pellucid colourless substances, to the permanent colours of various kinds of matter; since the latter evidently depend on other properties, which determine, or occasion the reflection or transmission of some particular sort or sorts of rays, and an absorption or disappearance of the rest; and these I conceive to be certain *affinities*, or *elective attractions*, existing in or between the differently coloured matters and the particular sorts or rays of light so absorbed or made *latent*; and of which many instances and proofs will, I think, be found in the subsequent parts of this work.

sible la pesanteur spécifique des oxides métalliques, y produit de grands changements de couleurs," &c.

Next after the diamond and amber, we find that spirit of turpentine, linseed oil, olive oil, camphor and alcohol, or rectified spirit of wine, possess greater refracting powers, in proportion to their respective densities, than any of the other substances contained in Sir Isaac Newton's table, and yet they are all *permanently destitute of colour;* a fact which does not seem to indicate any connexion between the refractive power of a substance and its natural *permamanent colour.* Nothing seems to act so powerfully and extensively in producing and changing those affinities, or elective attractions, from which the permanent colours of different substances arise, as pure vital air, or its basis, the oxygene; which, indeed, seems to owe its elastic, or aërial form, to a portion of light as well as heat. Scheele demonstrated that gold, silver, &c. were revived from their oxides by the contact of light; and M. Berthollet has proved, that, in producing this effect, the light occasions a separation of oxygene, in the form of pure vital air. Light also separates oxygene from various other substances, to which it would otherwise remain united, under great degrees of heat.

We are at this time well acquainted with the constituent parts of the acid of nitre: it undeniably consists of nitrogene or azote, rendered acid by its combination with a certain portion of

oxygene, or the basis of vital air. When these are combined in a certain proportion, the acid or compound is colourless, as we see it in aqua fortis, or nitric acid: but if this colourless acid, in a transparent glass vessel, *partly filled*, be exposed to the rays of the sun, or the light of a fire, an alteration will take place in the proportion of its ingredients; since the light will combine with a part of the oxygene, and cause it to become elastic and fly off, and the nitrogene will consequently predominate in the remainder; which, becoming *nitrous acid*, merely in consequence of this predominance, will assume first a yellow, then an orange, and afterwards a high vivid aurora, and even a red colour, intensely affecting the sight. But if the glass vessel containing the colourless nitric acid, were *completely filled* with it, and closely stopped, no such change of colour would take place by any degree of exposure to the sun's rays or other light; because, in this case, there would be no sufficient space or room to allow of a separation and escape of the oxygene. When nitrous acid has been made to assume the colours before mentioned, if the glass vessel containing it be hermetically sealed and kept for some time in the dark, the oxygene, by losing its light, will lose its elasticity; and being again re-absorbed by the nitrous acid, the latter will become colourless, as before. Mr. Keir mentions an orange-coloured nitrous

acid, which, by long keeping, became green, and afterwards of a deep blue; and Bergman says, that if, to a concentrated red nitrous acid, one-fourth part of the quantity or measure of water be added, the colour will be changed to a fine green; and to a blue, by the addition of an equal measure of water; and that double its quantity of water will destroy the colour. Here then we have an example of all the various colours produced by the two species of air which almost exclusively compose our atmosphere, when deprived of their elasticity, and mixed in particular proportions with more or less dilution by water.

In the same manner, colourless nitric acid, when applied to wool, silk, fur, or the skins of animals, their nails, horns, &c. renders them all not only yellow, but orange, and even aurora-coloured. M. Berthollet thinks, these changes are produced by a kind of combustion; but I am persuaded they are the result of a combination of the oxygene with the nitrogene, which he has proved to be a constituent part of all animal substances; these changes being exactly similar both in their nature and origin, to the changes of colour produced as before mentioned in the nitrous acid. Were these colours the effect of combustion, why are they not likewise produced in the same manner upon linens, and cottons, which are without nitrogene, but con-

tain a great portion of the basis of charcoal, and ought therefore to be more liable to be acted upon in the way of combustion, than animal substances?

Long before the properties of the several kinds of air were known, many changes of colour had been noticed as produced by the application or action of light; and indeed its effects are so remarkable, in many cases, that no one can doubt of its powerful agency in these and other respects.* The principal thing to be ascertained on this point is, whether the colours which accompany, or require the application of light, result in each particular instance directly from a combination of it with the coloured substance, or indirectly from its particular action in occasioning either a separation of oxygene, or a combination thereof with the coloured matter? M. Sennebier attributes the effects of light upon colouring matters, to a *direct* combination of the former, with the latter;† but of

* Light not only contributes most efficaciously to the production of some colours and the destruction of others, but it greatly weakens the texture, and fibres of silk, linen, cotton, &c. when they are long exposed to the direct action of the solar rays; as may be seen in window curtains, blinds, &c. which, from that cause only, will, in a few years, tear as readily as brown paper.

† See "Mem. Physico-Chymiques sur l'Influence de la Lumiere Solaire," &c. tom. ii. and iii.

this, though it may be true, he has not alleged any sufficient evidence, so far as I am capable of judging ; and there are many facts which prove that the sun's beams, in some cases, favour the action of oxygene upon, and its combination with, colouring matters; whilst in *other cases*, it manifestly produces *opposite* effects upon these matters, by decomposing or separating some of their constituent parts, and especially the oxygene previously united to them: and probably these are the only ways in which it affects colours; it being doubtful whether light ever unites itself so *permanently* to any matter as it must do, to produce the *lasting* colours given by dying.

From the experiments of Beccari, Meyer, Schulz, Scheele, and Sennebier, it appears that muriate of silver (horned silver), which is nearly of a pearl white, changes to a violet colour, and from thence to a black, in the space of a very few minutes, when exposed to the sun's rays in a transparent glass; and this change Sennebier ascribes solely to the action of light; since, as he maintains, the muriate of silver will invariably retain its whiteness, though exposed either to heat or cold ; and in a moist or a dry air, or in *vacuo*, if secured from the accession of light, and of what he calls phlogistic vapours (probably sulphuretted hydrogenous gas), and that it loses its whiteness only by the application of light, and then only in propor-

tion to its quantity or intensity; so that when the sun's rays are copiously applied by a lens, the muriate of silver is rendered violet coloured in a single second. By covering the muriate of silver with four thicknesses of white paper, its whiteness was preserved; one, two, and three thicknesses retarded, but did not prevent its finally becoming violet and black. Mr. Sennebier found that the different rays of light, under the same circumstances, coloured the muriate of silver with different degrees of celerity; *i.e.* the *violet* rays in 15 seconds, the purple in 23 seconds, the blue in 29, the green in 37, the yellow in 5 minutes and 30 seconds, the *orange in* 12 *minutes*, and the *red in* 20; but the rays of the three last colours would not, as he relates, produce such a dark violet colour in any length of time, as was thus quickly produced by the more refrangible rays.* I have also witnessed some of these, and other changes of colour, taking place in muriated or horned silver, which manifestly result from an incipient reduction or revival of the metal, and with it a production of the dark colours which silver always manifests in that state; and in confir-

* These facts which formerly appeared unaccountable and extraordinary, may now be readily explained by those which Mr. Herschell subsequently discovered and published (i. e. in 1800) respecting the composition of the sun's beams, and the very different powers of their several constituent rays.

mation of this, I need only mention what I have several times observed, that though muriated silver, placed at the bottom of a colourless glass vessel, nearly filled with water, was made violet coloured in about two minutes, by the weak light of a room, having a single window only, and in a cloudy day; yet a direct application of the sun's rays for many days produced no change of colour, when the muriated silver was covered with muriatic acid instead of water; a revival of the silver not taking place, whilst so much uncombined muriatic acid remained in contact with it.

A solution of silver in the nitric acid likewise changes colour by the action of light, and becomes black *thereby*, as well as by the application of inflammable substances, of calcareous earth, and every thing which separates a sufficient portion of the oxygene. It also gives the skin a black colour, which cannot be effaced, but by a removal or change of the skin itself: it tinges the hair, nails, and other animal substances, in like manner, because they occasion a separation of so much of the oxygene as is necessary for that purpose.

Mercury dissolved in nitric acid, being washed with water, affords a yellow oxide, which, when exposed to the light in a transparent colourless glass vessel, will become black on the side to which the light is applied, even where the vessel is filled

with water; because the light extricates a part of the oxygene; this yellow oxide being a preparation of mercury, with but a very small proportion of acid. The red precipitate, and several other preparations of mercury, have their colours changed even under water, by similar means. The white or colourless solution of mercury, by the nitric acid, when applied to animal and inflammable substances, tinges them purple and black, in the same way, and from the same cause, as they are tinged by the solution of silver. Similar effects happen with the solution and oxide of bismuth, which last is therefore used to blacken hair when mixed with pomatum. Almost all the other metals afford instances of changes of colour more or less remarkable, depending both upon the accession and the separation of oxygene; and in many of these light has a considerable influence in promoting one or other of these effects.

In all the instances lately mentioned, blackness was produced by a separation of vital air from the metallic basis; but there are others in which it results from the addition or accession thereof. Arsenic, as Mr. Chaptal mentions, when first sublimed, is of a shining grey, or steel colour, but blackens speedily by exposure to the air ("noircit promptement à l'air;") and he likewise observes, that "manganese, precipitated by an alkali from its solution, was found to be a whitish gelatinous

substance, which soon changed colour, and became *black*, by the contact of air; that, having been a witness of this phenomenon, he could only attribute it to the absorption of oxygenous gas, and found this to be the case, by shaking the white precipitate in glasses filled with that gas, by which the black colour manifested itself in one or two minutes, and a considerable part of the gas was found to have been absorbed." Elémens de Chymie, tom. ii. p. 260.

The preceding instances relate to mineral and inorganical substances; there are many, however, which relate to the colours of vegetable and animal matters. Ray, in his Historia Plantarum, printed in 1686, vol. i. p. 15, appears to have discovered, by several experiments and observations, that the green colour of plants depended chiefly upon the influence of light: he had found that they were *green*, whilst vegetating under a transparent glass bell exposed to the light, and that when growing in obscurity under an opaque vessel, they lost their green, and acquired a pale whitish yellow; their stalks, at the same time, becoming long, slender, and feeble, and their leaves small. And these effects he ascribed to the want of light, rather than of either air or heat. "Nobis tamen non tam aer quam lumen, luminisve actio coloris in plantarum foliis viridis caussa esse videtur."—"Ad hunc autem colorem inducendum non requiritur

calor," &c. Mr. Bonnet has since confirmed Ray's conclusions upon this subject, and added several curious facts, resulting from a variety of experiments related in the fourth and fifth volumes of his works: but it is Mr. Sennebier who has done most, and carried his inquiries farthest respecting it, as appears by his "Memoires Physico-Chymiques sur l'Influence de la Lumiere Solaire, &c. in 3 vols. 8vo.

It is now well ascertained, that vegetables, growing in the light, give out oxygene gas, (pure vital air;) and Dr. Ingenhouz, by a great number of experiments, has proved, or conceives himself to have proved, that in the dark they give out the carbonic acid gas (fixed air;) though this has been doubted by others, and particularly by Mr. Sennebier, who conceives, that, in these cases, it was the pure air vitiated by some disease or decomposition of the plant itself: Dr. Ingenhouz, however, in his last publication, adheres to his former opinion, and supports it with new facts and arguments. Be this, however, right or wrong, there is no room to doubt but that healthy plants, growing in the solar light, decompose both water and carbonic acid gas; and, appropriating to themselves the hydrogene, or inflammable air (which is a constituent part of water), and the carbonaceous matter, or basis of the carbonic acid, with perhaps a small portion of the oxygene, they

emit the rest in the form of vital air, which the light seems to separate, by combining with and rendering it elastic, in the same manner as it separates the oxygene from the calces or oxides of metals, &c. But when plants vegetate in obscurity, no such separation can take place: indeed, the water imbibed by the plants seems not to be properly decomposed, unless their living powers be aided by the stimulus of light, and by its affinity for the oxygene. There is, therefore, an accumulation of this latter substance, and a want of inflammable air to compose the resinous matter, by which the green colour of the plant is produced; and this colouring matter being very sparingly formed, and at the same time combined with an excess of oxygene, the plant, instead of its natural greenness, exhibits only a white or pale straw colour. Mr. Sennebier found that plants, in this state, received a deeper green, and in less time, by exposure to the *violet* rays of light, than to those which were less refrangible, as was the case in colouring the muriate of silver. He also found that plants left to vegetate without light, under vessels filled either with nitrogene, or hydrogene, did not lose their green colour, as when surrounded by common atmospheric air. In carbonic acid gas they soon perished. Dr. Ingenhouz also observed, that on mixing a little hydrogene with either the common or the vital air in which a

plant was growing, under a transparent glass, the green colour of the plant soon became deeper. In these cases there seems to have been an absorption of the hydrogene, affording an increase of the resinous colouring matter.

Mr. Sennebier also found, that the red tinctures of orcanette,* safflower, kermes, gum lac, and cochineal, were made yellow by exposure to the sun's rays; and the tincture of dragon's blood was thereby deprived of all colour: in these cases the *alcohol*, or spirits of wine, assisted the action of the sun's rays in decomposing the several colouring matters, probably by abstracting and combining with their oxygene; because it was found that the *aqueous* infusions of orcanette, kermes, and cochineal, suffered no change by the like exposure; though indeed the infusions of safflower, dragon's blood, and gum lac, were changed by it; perhaps because they contain a resinous matter which might have co-operated with the rays of light, in the same way as the spirit of wine is supposed to have done. Mr. Sennebier observed, that the petals of damask roses afforded a kind of brick colour to spirits of wine, when put into it; and that this, by a few minutes exposure to the common light, became of a fine violet-colour; which, however, was soon destroyed, by a direct application of the

* *Anchusa tinctoria.* Lin.

sun's light, unless when a few drops of some of the strong acids were added; in which case, the colour withstood the sun's rays for several months. From these instances I conclude, that the colour of roses depends on a certain proportion of oxygene; that the light, aided by the affinity of the spirits of wine, for oxygene, produces a separation of it, and destroys the colour; but that these effects are obviated, as might be expected, by the addition of acids containing and affording a supply of oxygene. And that this was the fact, seems evident from this observation, made by Mr. Sennebier, that when the petals of the roses had been rendered white, by imparting their colour to the spirit of wine, they regained it on being taken out, and exposed to the air, even in a dark place; though they did it much quicker in the light; but not at all in a vessel containing only nitrogene surrounded by quicksilver, even when aided by an immediate application of the sun's light; which clearly proves, that the restitution of oxygene was indispensably necessary to the restitution of their colour. In the same way *sulphureous* acid whitens roses, by depriving them of their oxygene; and the *sulphuric* acid revives the colour, by restoring it.*

* The sulphureous or volatile vitriolic acid, not being saturated with oxygene, is disposed to attract it from other matters in contact with it; and by so doing, it not only whitens roses, but silk, wool, and other substances, rendered yellow by being united to a certain portion of oxygene.

Mr. Sennebier also found that the red skins of peaches became white in spirits of wine, like the petals of roses, and, like them, regained their colour by exposure to the air; as did also the red skins of plumbs. He likewise observed, that the water-colours used by painters, if covered by a solution of fish-glue or isinglass, and then varnished, withstood the action of the sun's rays much longer than if varnished without the fish-glue; which last seems to have prevented the varnish from co-operating with the light in extricating the oxygene of the colouring matters, as, from its inflammable nature, it would do, if in immediate contact with them. Negro children when first born are white, as plants are when they first shoot above the earth, though they become *black* in a few days, after being exposed to the light, as plants become green, and probably from the same cause.

In like manner the hair of such kittens, puppies, &c. as are intended by nature to become decidedly black, is immediately after birth only of a brownish black; but it gradually darkens externally. Though the hair of the blackest cats and dogs will be found, even in old age, not to be black at the *roots near the skin,* where it is most secluded from the light.

Mr. Sennebier mentions, upon the authority of Scheele, that the Nereis lacustris, is *red* whilst living in places accessible to the sun's rays, and

lent effects; an operation which, after I had at first accidentally succeeded in performing it, I found liable to so many failures, from the dificulty of ascertaining, at any time, how much of the metal had been actually dissolved, that I have long ceased to expect that it can ever be adopted with advantage by dyers.*

I have mentioned, at p. 305 of my first volume, that a fine lasting black, without iron or any other basis might be dyed upon blue cloth, from a species of lichen, called *rags*, or stone rag in the North of England, (the lichenoides pulmonium reticulatam vulgare marginibus peltiferis, of Dillenius); and if this could be readily and copiously obtained it would, probably, deserve to be preferred to madder and weld for rendering blue cloth black; and, indeed, I have found, that the brownish yellow which alder bark affords upon the aluminous basis, may, for this purpose, be advantageously substituted for that of weld.

* The best, and, perhaps, only method of doing this, would be first to ascertain, as nearly as possible, the quantity of iron in its metallic state, which will produce the best effects when *totally* dissolved by, or with the soluble part of a given quantity of galls; but it would be highly inconvenient, and, in several respects, disadvantageous, to wait long enough for this *complete* dissolution of the iron, unless it were first brought into the state of *iron filings*; which, for general use in dyeing black, would be attended with more trouble and expence, than any advantage to be expected from this change seems likely to be compensate.

Of the Application of the Black Dye to Silk.

The fibres of silk not being organized like those of wool, do not so readily admit the black dye as the latter. Dr. Lewis (in his Philosophical Commerce of Arts) observes, that " woollen and silk are both dyed of a permanent deep black, but with this difference, that what the woollen dyer effects by three or four dippings of the cloth, in his dyeing liquor, the silk dyer scarcely obtains from twenty or thirty dips."

Though raw silk imbibes the black dye with as much facility as that which has been deprived of its gum, yet, when dyed, the black appears less intense and less fixed in the former than in the latter; and it is, therefore, made previously to undergo the usual boiling, with one-fourth or one-fifth its weight of soap, during three or four hours: by this operation, indeed, silk often loses nearly one-fourth of its weight, but this loss is more than compensated by that which it gains from the black dye.

As the affinity of silk with the soluble parts of galls is greater than with the iron contained in a solution of the sulphate of that metal, it is thought most advantageous to begin by first applying the former; and for this purpose about one-half as much in weight of Aleppo galls as of the silk to be dyed, is boiled in a suitable proportion of water, three or four hours, after

white when living in obscurity; and M. Dorthes asserts, (Ann. de Chymie, tom. ii.) that most of the *larvæ* of insects, inhabiting the dark cavities of animals, trees, fruit, &c. are white; and that having forced a variety of them to live under transparent glasses, exposed to the light, they gradually became brown. But the most *decisive* and *interesting* proof of the action of light, in producing various colours by promoting a separation of oxygene from animal colouring matter, will be found by the effects which I shall notice hereafter, when treating of the celebrated *purple of the ancients*.

The preceding are examples of animal and vegetable colours produced, changed, or destroyed, either by the action, or the want of light, exerted in separating their oxygene. In many other cases, however, the affinity of light is very differently exerted, upon colouring matters, by promoting a combination of oxygene with them.

The green colour of the leaves of plants resides in a resinous substance, which being dissolved and extracted by spirit of wine, produces a green tincture; and Mr. Sennebier having exposed this to the rays of the sun, in a clear transparent glass, but half filled, he found, upon repeated trials, that the colour was generally destroyed in about twenty minutes, and a yellowish substance was precipated to the bottom;

which seems to have been the colouring matter saturated with oxygene: but when the glass was completely filled with the green tincture, and closely stopped, he found, that the strongest action of the sun's rays upon it, during four months, did not weaken in any degree, the green colour, because all oxygene was excluded, and the rays of light, without it, were unable to effect any change. When nitrogene was inclosed in a vessel partly filled with this green tincture, the latter suffered little or no change, by long exposure to the direct action of the sun's light; but if, instead of this, he substituted pure vital air, the green colour was most rapidly destroyed. Mr. Sennebier also found, that the dark red juice of black cherries very soon lost its colour, when exposed to the sun's rays, but that a tincture of those cherries in spirit of wine, preserved its colour in the same circumstances; the spirit of wine, as I conceive, affording a covering and defence to the colouring matter of the cherries, against the action and farther combination of oxygene or vital air. Here the effect was directly opposite to that with roses, lately mentioned. M. Fabroni has also asserted, (Ann de Chemie, tom. xxv.) that the fresh juice of the aloe succotrina angusti folia, by mere exposure to the atmosphere, either with or without the contact of light, soon became red, first, at the parts most accessible to

the air, and afterwards in other parts, and that it finally became of a very dark, but very lively purple: and he convinced himself that this change resulted exclusively from an absorption and combination of oxygene. There are many other instances of changes of colour by an absorption of oxygene, with or without the assistance of light; and in particular two experiments made by M. Berthollet. In the first, he "inverted, over mercury, a bottle half full of the green solution (employed by Mr. Sennebier,) and exposed it to the light of the sun; and when the colour was discharged, the mercury was found to have *risen in the bottle,* and consequently vital air must have been absorbed; the oxygene having united with the colouring matter." In the second experiment, he "placed a tincture of turnsol, in contact with vital air, over mercury, in the dark, and he also exposed a similar tincture to the light of the sun; the former continued unchanged for a considerable length of time, and the vital air had suffered no diminution; but the latter had lost much of its colour, was become red, and the air was in a great measure absorbed," &c.

M. Fourcroy has also demonstrated, (see Ann. de Chimie. tom. v.) that a variety of colouring matters, extracted by water, and left exposed to the air, combined with its oxygene, and thereby not only assumed new colours, but

became much more fixed and permanent; which happens likewise in the production of indigo, as will be proved hereafter.

I have now noticed the principal facts respecting the powerful agencies of solar light, in producing, changing, and destroying mineral, vegetable, and animal colours; which agencies as far as we know, or can judge, seem to be principally, if not exclusively, exerted, in promoting, under particular circumstances, and with particular coloured, or colouring, matters, *an abstraction or diminution of their oxygene;* and with other matters and other circumstances, in causing a *new* or *additional combination of it.*

These *opposite* effects, may be now explained in consequence of recent discoveries respecting the sun's beams. Newton taught us, that when the rays of which they consist are transmitted through a triangular prism, and received upon white paper, those *most distinctly perceptible*, are the red, orange, yellow, green, blue, indigo, and violet; and that if the coloured image or spectrum be divided into 360 parts, the red will occupy 45 of these parts, the orange 27, the yellow 48, the green 60, the blue 60, the indigo 40, and the violet 80; and that the red are refracted the least; the violet the most; and the other rays inversely in the order in which they have been arranged, and he supposed them to vary in the size of their particles, according to

this order; those of the violet being the smallest. It has, however, been recently ascertained by Dr. Herschell; (see Philosoph. Transactions for 1800, p. 267.) and by the experiments of Sir H. Englefield and others, that the solar beams comprehend three sorts of rays; viz. one which excite heat and promote oxidation, or the combination of oxygene with different matters; another which illuminate; and a third which *de*oxidize, or cause the separation of oxygene. He found the yellow, and the pale green rays, to possess the greatest power of illuminating, and the violet the least; and the red rays to possess the greatest power of heating, and the violet the least. But beyond the *red* rays, there are certain *invisible heating* rays, which raise the thermometer higher than even the red rays. Moreover, at the other extremity, a little beyond the *violet* rays, not only the thermometer *is not affected*, but there are *there*, certain *other invisible rays*, which produce, very efficaciously, particular chemical effects; one of which is that of changing from *white to black*, the colour of a precipite of the muriate of the silver just made. This is, indeed, done most rapidly, by the *collected* rays of the sun's beams, but the separate rays do it with greater energy, in proportion as they are nearest to the invisible rays, at the *violet extremity*. Sir H. Davy, also states, that "if moist horned silver,

(muriate of silver) be exposed to the different rays of the prismatic spectrum, it will be found that no effect is produced upon it by the least refrangible rays, which occasion the greatest heat, *without light*; a *slight* discolouration only, will be occasioned by the red rays; the effect of *blackening*, will be greatest towards the *violet* part of the spectrum; and in a space beyond the violet, where there is no sensible heat or light, the chemical effect will be very distinct." "This observation, (he adds) made by M. Ritter and Dr. Wollaston, proves that there are rays more refrangible than the rays producing light and heat; and from the observations of M. Berthollet, it appears that muriatic acid gas is formed, when horn silver is blackened by light, so that they may be called *hydrogenating* rays," p. 211. Sir H. Davy farther observes, in the next page, that he "found that the puce (or Flea) coloured oxide of lead when moistened, gradually gained a tint of red in the least refrangible rays, and at last became black, but was not affected in the most refrangible rays; and the same change was produced, by exposing it to a current of hydrogene gas. The oxide of mercury procured by a solution of potassa and calomel, exposed to the spectrum, was not changed in the most refrangible rays, but became red in the least refrangible rays, which

must have depended upon its absorbing oxygene."

Dr. Wollaston found that the substance called gum-guaiacum, when exposed in the most refrangible rays, beyond the violet extremity, was changed from its yellowish colour to green; and that it was again made yellow, by the least refrangible rays. One of which effects must have resulted from a separation, and the other from an absorption of oxygene.

The oxygenating power of the solar rays is, however, that which M. Berthollet seems exclusively, and as I think erroneously, to insist upon, as occasioning, either with or without the aid of light, all the changes and injuries to which animal and vegetable colouring matters are liable; and he deems the action and effects of oxygene in these cases to be similar to those of *combustion.** "In considering the effects of air on colours (says he,) it is necessary to make a distinction between those produced by metallic oxides, and those produced by the colouring particles," meaning those of an animal or a vegetable nature; the

" * Cet effet doit être considéré comme *une véritable combustion.* Par là, le charbon qui entre dans la composition des parties colorantes, devient prédominant, and la couleur passe ordinairement au jaune, au fauve, au brun; ou cette dégradation en s'alliant avec ce qui reste de la premiere couleur, produit d'autres apparences."

modifications of the former are, says he, "entirely owing to different proportions of oxygene;" but I have been led by observation, he adds, "to form a different opinion of the latter;" meaning those with which the oxy-muriatic acid had exhibited different phenomena, sometimes discharging their colour, and producing whiteness, but most frequently rendering them yellow, fawn, or root-coloured, or brown or black, according to the intensity of its action: and he remarks, that he had found, by comparison, that when the colouring particles were rendered yellow, fawn-coloured, or brown, by the oxy-muriatic acid, effects were produced similar to those of combustion; and that they were "owing to the destruction of the hydrogene; which, as it combines with oxygene more easily, and at a lower temperature than charcoal does, leaves the latter *predominant*; so that the *natural colour of charcoal* is more or less blended with that which before existed;"* and as

* Messrs. Lavoisier, Bertholiet, and other pneumatic chymists, have considered the *black* colour of charcoal as *naturally* existing in the vegetable matter from which it is formed, and not as the result or effect of combustion. To me, however, charcoal seems to be a kind of vegetable *oxide*, consisting of the carbonaceous basis, united to a certain portion of oxygene, enough to render this basis black (as it occasions the blackness of manganese,) but not enough to saturate and convert it into carbonic acid gas. Hard woods contain so great a portion of

"the light of the sun considerably accelerates the destruction of colours," he concludes that

the basis of charcoal, that if it really existed therein, with its black colour, previous to combustion, it is impossible to conceive how they should ever appear white, yellow, red, &c. since in dying, &c. we find, that laying other colours upon a black ground, increases the blackness. Neither do I think that this blackness is the only circumstance in which charcoal differs from its basis, or the state in which the vegetable part thereof existed previous to combustion: on the contrary, its oxidation, or combination with oxygene, manifestly gives it new and very remarkable properties. This basis, is, indeed, never converted into charcoal, but by such a degree of heat, and in such circumstances as must necessarily occasion its combination with oxygene; and when this conversion is made, the charcoal is rendered infinitely more indestructible than any other vegetable matter, as it will resist the combined action of sun, air, moisture, &c. for hundreds of years; and indeed it can hardly be destroyed, but by such farther combustion and combination with oxygene, as will change it into carbonic acid gas. This indestructability, or stability, as well as the *black colour*, of charcoal, therefore manifestly result from the combination of oxygene with its basis. Did it really exist, *with its black colour naturally* in wood and other vegetables, why do we not find it remaining *intire* after the other parts of vegetables are separated or destroyed by fermentation, putrefaction, &c.? And why does it decay and rot with them *undistinguished*, contrary to what happens when it occurs separately, in the form of charcoal? And why, when it has assumed this form, will it not recombine with matters similar to those which were separated from it, and enter with them into fermentation, &c. as it surely ought to do, if it had acquired no new property, and only been left in a distinct form, by the simple *abstraction* of those matters.

The preceding observations respecting charcoal, were

it ought, if his theory be well founded, "to favour the combination of oxygene, and the combustion thereby produced."*

first printed in the year 1793. It did not then accord with my purpose, to enter upon a minute examination of the several constituent parts of charcoal; I wished only to convince my readers that it was not a *simple* substance, *naturally* formed, and existing with its *black* colour in vegetable matters; and that when dyed colours faded, and became brown or dark coloured, by exposure to the sun and air, this change did not happen, as M. Berthollet had conceived, because the supposed *naturally black colour* of the charcoal, contained in the vegetable dyes, was rendered *visible,* and *predominant,* by a separation of the other matters, which had been in union with it, (" de sorte que la couleur *propre* au charbon, se mele plus ou moins, a celle qui préexistait." Berthollet, tom. i. p. 133). To produce this conviction, I thought it only necessary that my readers should, without bias, exercise their senses and understandings. Since that time, the nature and composition of charcoal have been nearly ascertained; but I think I may claim the merit of having first occasioned a distrust of the doctrine of M. Lavoisier on this subject, and thereby promoted the subsequent experiments and inquiries.

Dr. Thompson, one of our best systematic chymical writers, makes the following observation in the first volume of his system of chemistry, viz. " Lavòisier supposed pure charcoal to be a *simple* substance, and for that reason invented the term carbon to distinguish it. But other philosophers were of opinion that charcoal is a compound body, and that it is composed of carbon and oxygene. The truth of this opinion, *which, as far as I know, was first maintained by Dr. Bancroft,* has been lately established by the experiments of M. Guyton Morveau." To these have been more recently added, the accurate researches of Messrs. Allen and Pepys.

* Elements of the Art of Dying, chap. iii.

In thus ascribing the decays of vegetable and animal colouring matters *generally*, to effects or changes similar to those of *combustion*, M. Berthollet has, I think, gone farther than is warrantable by facts. It cannot, I am persuaded, be his intention that we should apply the term of combustion to alterations which result from a simple addition of oxygene to colouring matters, without any destruction or decomposition of their constituent parts; though a great many of the alterations and extinctions of these colours evidently arise only from such simple additions. The nitric, sulphuric, and other acids containing oxygene, have the power not only of weakening, but of rendering latent for a time, the colours of many tingent matters; not however by any effect which can properly be denominated a combustion, but rather by a *change* in their several *affinities* or attractions, for *particular rays* of light in preference to other rays; but none of their parts being destroyed, or carried away, the addition of an alkali, or of a *calcareous carbonate*, will generally undo such alteration, and restore the original colour, by decomposing and neutralizing the acid or oxygene which had caused the alteration. Of this numerous instances might be given; it will however be sufficient to mention, what most people have seen, that ink, dropped into a glass

of diluted nitric, or vitriolic acid, will lose its colour, and that it may be again restored by adding a suitable portion of vegetable or fossil alkali; and that this may be done several times with the same ink, and therefore the change, or loss of colour, could not have been the effect of combustion. The production and existence of each particular colour, depends upon precise, and often very minute proportions of the constituent parts of the colouring matter, and it may, therefore, be changed, and in many cases even destroyed, by every thing capable of *altering these precise proportions;* and as this may be done by very opposite causes, we are not warranted in ascribing the decays of colours *generally* to combustion only, or indeed to any one cause exclusively. Many colours are as much injured by muriatic acid, as by the sulphuric or nitric: and as the former is now generally admitted to contain *no oxygene,* or to contain it *so inseparably combined,* that no combustion can take place by means thereof, we must necessarily infer, that the effects of the muriatic acid, are not occasioned by combustion, which muriatic acid does not produce.

Mr. Sennebier exposed a great variety of woods to the action of the sun and air, and found all their colours very soon affected. The white woods were generally made brown, and the red and violet changed either to *yellow* or black.

Guaiacum was rendered green ; the oak and the cedar *were whitened,* as were the brown woods generally ; several of these effects, and especially the whitening, do not resemble those of combustion, any more than the *bleaching of wax and tallow,* by exposure to atmospheric air.

The colour of each particular substance results from its peculiar constitution, producing in it a particular affinity or attraction for certain rays of light, and a disposition to reflect or transmit certain other rays ; and in this respect it may doubtless suffer very considerable changes, without any effects similar to those of combustion. And indeed the changes of colour which arise from the access of vital or atmospheric air, seldom resemble those which the mere predominence of blackness (the supposed natural colour of charcoal) would produce ; though this may have been the case with the colouring matter of brown or unbleached linen, upon which M. Berthollet's experiments were principally made.

But whether the action of vital air, or its basis, in promoting the decays of a few particular colours, ought to be denominated a combustion or not, I am confident that, at least, some others are liable to be impaired, *not so much by an accession of oxygene, as by the loss of it ;* an effect, of which I have already enumerated several examples, among animal and vegetable,

as well as mineral substances, deriving their colours from a combination with certain portions of oxygene; and of these I might easily augment the number.

Hook and Lower long since noticed the difference of colour in arterial and venal blood; and it has been since proved, by numerous experiments, that the fine vermilion colour of the former, is produced solely by vital air, which it is capable of acquiring even through bladders, the coats of blood vessels, &c. And very recently, Mr. Hassenfratz seems to have proved (see Ann. de Chimie. tom. ix.), that as this fine red colour is gained by a dissolution of oxygene in the arterial blood, so it is lost, and the dark colour of the venal blood restored, by a separation of the oxygene.

That the blue colour of indigo absolutely depends upon a certain portion of oxygene, has been already mentioned, and I shall hereafter give some curious illustrations of this fact, from which it will appear that a solution of indigo, by losing its oxygene, may be rendered as pellucid, and, excepting a very slight straw-coloured tinge, as colourless as water, and that it will afterwards speedily return, through all the shades of yellow and green, to its original deep blue, only by exposure to atmospheric or vital air. Similar to this is the fact long since observed by the Abbe Nollet, of the tincture of

archil (orchella) employed to colour the spirit of wine used in thermometers, which after some time loses its purple colour, but soon recovers it again upon being exposed to atmospheric air. And this also happens to the infusion of turnsol, and to syrup of violets, which both lose their colours when secluded from air, and regain them when placed in contact with it.* Many other examples of the like effects might be mentioned here; but to avoid repetitions, I beg leave to refer my readers to subsequent parts of this work, in which I shall have occasion to instance various animal and vegetable colours, produced solely by the contact of vital or atmospheric air; and some others, which, when given by dying or calico printing to wool, silk, cotton, &c. though unable to sustain a single day's exposure to the sun and air without manifest injury, were found to receive none from the action of acids of considerable strength, but, on the contrary, were in some degree preserved by being wetted with them, and especially with the citric acid. But the same colours, if covered with linseed oil, were found to decay more quickly from exposure to the sun and air, than if uncovered. These

* Oxygene is also absolutely necessary to produce the blue colour of Prussian blue, and the black colour of ink. These facts are too notorious to require proof.

colours therefore could not owe their decays to the contact or combination of oxygene, because they were not only unhurt, but benefited by its agency in the citric, and other acids containing it; and also because they were soonest impaired when secluded from it by a covering of linseed oil. Probably the decay of these colours was occasioned by a loss of at least some part of the oxygene, necessary to their existence, and which the linseed oil assisted in depriving them of, by its known affinity therewith.

In forming systems, we are apt to draw general conclusions from partial views of facts. And this even, M. Berthollet seems to have done, not only in ascribing the decays of vegetable and animal colours, *exclusively* to effects similar to those of combustion, but also in representing the oxy-muriatic acid as an accurate test or *measure* for anticipating, in a few minutes, the changes which these colours are liable to suffer, by long exposure to the action of sun and air; for though it should be true that the oxygenated muriatic acid, in weakening or destroying colours, gives up to them more or less of the oxygene, which it is supposed to have received from manganese; and that, by this new combination of oxygene, those affinities for particular rays of light upon which their colours depend, are liable to be destroyed; it is nevertheless true, that the changes of colour so produced are no certain indication of

those which the *combined influence of light and air* will occasion upon colours in general; there being, as I have already observed, and as I shall more fully explain hereafter, several colours which are very speedily destroyed by the latter of these causes, though they resist the action of the oxy-muriatic acid, even longer than the best colours given to printed calicos.

M. Berthollet well knows, since nobody has contributed more to ascertain, how much the properties of oxygene are diversified by each particular basis to which it unites; and it does not therefore seem warrantable to imagine, that its action would not be *modified*, as well as increased, by a basis so powerful as that of the common muriatic acid; or that the *united properties of both*, should exactly represent or resemble those of atmospheric air upon colours, any more than they do in the lungs, where, instead of supporting life, when respired, they would instantly destroy it.

Ten years after I had published the preceding observations, M. Berthollet, in the new edition of his "Elémens de Teinture," (between pages 131 and 147 of the first volume) recapitulated those parts of his former edition, which relate to this subject; and for doing so, he assigned the following motive, viz. parceque *Bancroft, dont l'autorité est pour nous d'un grand poids*, a prétendu réfuter la théorie qui y est établie,

et que nous desirons de mettre en état de *peser* ses raisons, et les motifs de notre opinion." He afterwards (p. 147 and seq.) notices some of my objections to his theory; and particularly that wherein I asserted, that colouring matters suffer, by the action of acids, and other substances, alterations which cannot be compared to combustion; to which he answers, "mais il n'est question dans les explications précédentes, que de l'espèce d'altération qui dépend de l'action de l'oxigène." This answer, were I not fully convinced of M. Berthollet's perfect candour and regard for truth, would seem to be either an evasion, or a mere petitio principii: and it certainly has the effect, of at least greatly *narrowing* the ground of our dispute; for I have never contended that *oxygene assisted by light*, does not *in some cases* injure colours in the way which M. Berthollet supposes, i. e. by combining with the hydrogene of the colouring matter, &c.; though I have objected to what seems to have been his opinion, that this was the *only way* in which the fading or decaying of colours ought to be explained; and considering the very opposite effects of light in regard to oxygene, which have been recently stated (and which M. Berthollet seems to have overlooked) it is impossible for me not to persist in that objection. It therefore still remains for us to ascertain, and distinguish the particular cases in

which oxygene, assisted by light, injures colours, by combining with the hydrogene of their respective colouring matters; but even if this were done, I should never be convinced that these matters had naturally contained ready formed *black charcoal*, and that the degradation of the faded or injured colour, resulted from a greater manifestation and *predominance* of this charcoal, with its supposed naturally *black* colour.

M. Berthollet next adverts to my objection that oxygene, far from destroying colours *generally*, is necessary to the existence of some of them, as e. g. of indigo. And to this he answers, "n'est-ce pas ce que l'on a dit? mais l'on a distingué les cas où il devient un élément de la couleur, et ceux où son action devient destructive." An answer which leaves us still to ascertain and distinguish the numerous colouring matters, of which oxygene is admitted to be an essential constituent, and which, from that circumstance, will be most susceptible of being injured, by a *deprivation* of oxygene, rather than by any addition of it; and even after this distinction shall have been made, it will not follow, as a necessary consequence, that the other remaining colours are not liable to suffer by effects very different from those of combustion.

Next in order, M. Berthollet notices my objection to his ascribing the degradation of *faded*

colours, to a predominance of charcoal, since many substances contain large proportions of it, without having any such colour as has been ascribed to its *excess;* and since the colour of charcoal itself, results only from an oxygenation of its basis. To this he answers, that without entering upon a discussion of my opinion on this point, "il s'agit seulement de sçavoir, si dans les circonstances dont il est question, le changement de couleur n'a pas de l'analogie avec celui que l'on observe, lorsque l'on distille une substance végétale :" and he seems to imagine (erroneously) that I had conceived the free access of the oxygene of the *atmosphere,* to be necessary to the browning of vegetable matter in that process, where there is otherwise, a sufficiency of oxygene. He next observes, that I had erred in supposing that his opinion was founded solely upon experiments made with the brown colouring matter of unbleached linen. But it will have been seen, that I only mentioned this as the matter upon which they "*were principally made.*"

And, finally, in regard to my objection to his assuming the action of the oxy-muriatic acid upon dyed colours, to be an *exact indication and measure* of that which they would suffer by exposure to the sun and air, he observes that he did not find in my work, an account of the experiments which I had announced, as sufficient

to prove that the effects of the oxy-muriatic acid, are sometimes at variance with those of the oxygene of the atmosphere. For this last observation there may have been some little foundation; but my readers will soon find it removed. I had, indeed, *occasionally* noticed some of these experiments, though not *collectively*; and others were intended to be also mentioned occasionally, in the second volume.

M. Berthollet next admits, that in comparing the effects of the oxy-muriatic acid, with those of the oxygene of the atmosphere, it is necessary to take into consideration the *greater condensation* of the oxygene in the former, together with "*L'action particulière de l'acide Muriatique*;" which, to my understanding, he certainly did not do in regard to the *latter*; and his not doing it, was the chief foundation of my objection. Even in his last edition (tom. i. p. 68) when treating of these effects, of the oxy-muriatic acid upon colours, he says "il agit alors *par l'oxigène qu'il abandonne*, et par conséquent *son action ne diffère que par l'intensité, de celle de l'air atmosphérique*;" so that even in this last edition, the particular action of the muriatic acid is *completely*, and as M. Berthollet now admits, *improperly* overlooked. He admits also, at p. 149, that it is necessary to distinguish between the effects produced by the oxy-muriatic acid, when *it completely discharges or extinguishes all colour*,

and those due to the combination of its oxygene, with the hydrogene of the colouring matters. I do not, however, believe, that there is any such difference in its action, or that it ever relinquishes any oxygene to combine with the hydrogene of the colouring matter in question; but that it destroys colours, by a power peculiar to itself, and inexplicable by any of its sensible qualities; a power manifested by effects the very reverse of combustion, since that highly *combustible* substance cotton, is bleached and rendered perfectly *white* by it, instead of being made brown or black, as it would be, if its mode of action were such as is here supposed.

M. Berthollet afterwards brings this discussion to a conclusion, by the following partial *concession*, at p. 150, viz.

"Si nous avons cru pouvoir réfuter les objections de Bancroft, sur la cause au moins la plus ordinaire de la dégradation des couleurs par l'air et la lumière, nous convenons que *les conséquences* de l'opinion que nous tâchons de maintenir, *n'auraient pas dû être étendues aux phénomènes que nous allons examiner*, quoiqu'on ne l'eût fait qu'avec beaucoup de réserve, et sans sortir des bornes d'une simple conjecture:" and he then proceeds to an examination of the phenomena, to which his doctrine on this subject *ought not to have been extended.* Of these, the principal relates to the yellow

colour produced upon wool, silk, and other *animal* substances, by the nitric acid; of which I have already given what appears to be the *only true* explanation at p. 37.

If I have sometimes thought it my duty to contest the opinions of M. Berthollet, I have always done it reluctantly, and I can feel no pleasure in prolonging, unnecessarily, a controversy with one, for whose decisions I feel so much deference, even where I believe it might be done with advantage on my side; I should, therefore, *here* terminate our discussion, were it not incumbent on me to state certain facts, which prove that the effects of the oxy-muriatic acid upon particular colours, are not an indication or measure of those changes, which would take place in the same colours, by exposure to the sun and air; and of which facts, M. Berthollet complains that he did not find a statement in the volume formerly published.

In the introductory part of my present volume, I have noticed the subsisting opposite opinions, concerning the nature and constitution of the substance, called acide muriatique oxigené, by the French chemists, and oxy-muriatic acid by the British; and which Sir H. Davy has lately denominated, *chlorine*. M. Berthollet and others, who believe oxygene to be one of its constituent parts, suppose that in bleaching or destroying colours, it acts by giv-

ing up to them its oxygene. Scheele had imagined that it did this, by combining with *phlogiston*, which was then thought to be the most important part of colouring matters ; and Davy, who like Scheele, considers his *chlorine* as a simple or *decompounded* substance, says (p. 243.) that it decomposes water by a double affinity ; " that of the hydrogene for chlorine, and that of the colouring matters for oxygene ;" to which last he ascribes, like M. Berthollet, the destructive action of chlorine upon colours, though he derives the oxygene from a different source. But if, as is here supposed, the destruction of colours by the oxy-muriatic acid resulted solely from the oxygene, which it either relinquishes, or separates from water, its effects on colours ought to resemble those of the nitric acid, when the quantity of oxygene which they severally afford, or put into action, is the same, and the effect of each, ought to be proportioned to the degree of acidity in the destroying agent. Many experiments have, however, convinced me, that few things are more unlike, than the several effects of the oxy-muriatic, and nitric acids, upon colours given by dying, &c. A very few of these experiments will suffice.—I put into a small phial, cuttings from three skeins of cotton yarn, which had been dyed, and sent to me by M. Chaptal, before he was called from his chemical labour to those of a minister of state,

One of these had received the Turkey red, another the nankeen buff, from an oxide of iron, and the third a black, as I believe, from madder and galls, applied upon the basis of iron, dissolved by the pyroligneous acid. Upon these colours I poured oxy-muriatic acid, which had been prepared by Mr. Accum, and kept secluded from light. Its acidity was so slight as to be hardly perceptible to the taste, and, I believe, it might have been put into the eye, without causing much pain. I found, however, that in less than two minutes, the colour of the Turkey red was much impaired, and in five, the yarn throughout the greater part of its surface had become *white*, without passing through any intermediate colour: and at the end of half an hour, but a very few specks of red, less than a pin's head, were perceptible. The buff colour at that time was found to have acquired a little body, and the black to have lost a little, but without ceasing to be still a good black.

At the same time, I put other cuttings of the same colours into another phial, and poured upon them undiluted aqua fortis, as prepared for the scarlet dyers; and I found that in a single minute the black which had withstood the oxy-muriatic acid, was changed to a buff colour, resulting solely from the *ferruginous* basis with which it had been dyed; and that the Turkey red began to exhibit the appearance of a *scarlet*, inclin-

ing to the orange; and this last, (of a *lively tint*,) became apparently its settled colour, at the end of an hour, when the buff, by acquiring more oxygene, was considerably *raised*. Here, then, was a very great diversity between the effects of the nitric and the oxy-muriatic acids, in no degree according, or proportionate to their degrees of acidity; that of the nitric acid being, I think, at least fifty, and, perhaps, one hundred times greater than that of the oxy-muriatic acid, (which being tasted, at the time when its action upon the Turkey red was strongest, and when, according to Davy's opinion, it must have already decomposed water, had not, to my taste, acquired any greater degree of acidity,) and yet the former, could only change the *complection* of the Turkey red to a *bright orange*, (probably by imparting oxygene to it) whilst the latter (not, as I conceive, by any such, or other *addition*, but by a complete *decomposition) had at once annihilated* all the colour, (leaving the cotton yarn white) as fast, and as far, as the decomposition took place; and this without any intermediate tint, which would not have been the case if the effect of the oxy-muriatic had, as M. Berthollet supposes, resembled combustion. And, on the other hand, the black, on which the oxy-muriatic acid could make but a very slight impression, was completely destroyed, (excepting the colour of its ferruginous basis) by the nitric acid.

Not unnecessarily to multiply instances of these *unequal* effects, I will barely mention, what will be stated more fully hereafter, that this slightly acid chlorine, or oxy-muriatic acid, was, by repeated experiments, found to produce more destructive effects on the fine purple of the Buccinum lapillus, than aqua fortis, or the strong undiluted oil of vitriol. Indeed, when I consider how generally and how powerfully the oxy-muriatic acid destroys animal and vegetable colours, whilst, from its very slight acidity, it cannot be supposed capable of either relinquishing, or separating from water, any portion of oxygene at all adequate to such effects, or in any degree comparable to the oxygene of the nitric acid, (and which the latter readily gives up, without producing any equally destructive effect on colours,) it seems to me as unreasonable, to ascribe this powerful agency of the former, to any portion of oxygene which it *can possibly bring into action*, as it would be to impute the death of a man, poisoned by two or three grains of the corrosive sublimate of mercury, to the single grain of chlorine or oxy-muriatic acid, which, combined with quicksilver, constitutes this sublimate.

If this chlorine be, as Sir H. Davy supposes, a simple elementary substance, it must produce its singularly destructive effects on colours, principally at least, by a power peculiar to it-

self, (which probably is a decomposing power;) and if it be, as M. Berthollet supposes, a compound, (of oxygene and muriatic acid) its peculiar energies must result from its composition; from the combined agency of its constituent parts, and not from the action of either separately, as has been supposed. And it may be presumed, that the same peculiar decomposing power, which enables the oxy-muriatic acid to annihilate colours with such extraordinary celerity, enables it also (by decomposition) to weaken and injure the texture of wool and other animal fibres, as it is known to do, in a much greater degree than the incomparably stronger sulphuric and nitric acids.

It now only remains for me to mention a few of the instances within my knowledge, proving that the action of the oxy-muriatic acid upon colours, is not an indication or measure of that which they would suffer, by exposure to the sun and air; and these instances I will select from an experiment, which was made carefully, and so recently as the 8th of July, 1812; when I put into an empty, glass-stopped phial, the following colours, upon separate bits of muslin, viz.

1st. A fast madder red dyed topically, by an eminent calico printer, upon a basis, from acetate of alumine, applied by the block.

2d. A fast yellow, dyed from weld upon the same basis, by the same calico printer.

3d. A fast yellow, dyed upon the same basis, from quercitron bark.

4th. A fine durable purple produced by the colouring matter of the buccinum lapillus, of which a full account will be given in the proper place.

5th. A logwood purple produced by mixing, with a strong decoction of that wood, as much muriate of tin, as rendered the former slightly acid, and after thickening the mixture with gum arabic, applying it in spots to muslin, which, after being properly dried, was washed with soap and water.

6th. A full bright yellow produced from a similar decoction of the quercitron bark, rendered slightly acid by an admixture of nitro-muriate of tin, made with two parts of nitric, to one part of muriatic acid, gummed, and topically applied in the same manner as the logwood purple, and in like manner dried, and afterwards washed.

7th. A similar yellow made from the quercitron bark, only substituting murio-sulphate of tin, for the nitrio-muriate. Upon these colours I poured oxy-muriatic acid, with which Mr. Accum had recently supplied me, (and which I had kept secluded from the light,) until the phial was full; after which, in less than two minutes, I found that the bits of muslin, with the *madder*, *weld*, *and quercitron*, colours dyed upon the *aluminious*

basis, were become perfectly white, by a complete extinction of their several colours. Whilst the logwood purple, that form the buccinum, and the quercitron yellows, with solutions of tin, were not apparently changed. But in about five minutes the logwood purple appeared to be losing body, as did the quercitron yellows soon after; and a similar effect soon became evident in the shell purple.

In about fifteen minutes, from the time when these colours were immersed in the oxy-muriatic acid, the logwood purple had nearly disappeared; and this was the case of the quercitron yellows in about three minutes afterwards, and of the shell purple about two minutes later; excepting that a part of the latter, as well as a part of one of the yellows given with tin, had each preserved a portion of colour, by having been protected, by other bits of muslin, from the sun's rays, which, as the sky was clear, had had free access to the phial containing them, at the window where this experiment was made; a fact which manifested the influence of solar light, in promoting the destructive action of the oxy-muriatic acid, on the colours in question.

It is here to be recollected, that the three first-mentioned colours, dyed upon the aluminous basis, would have resisted the action of sun and air for two or three months, and the madder for a much longer time, and yet they were completely de-

stroyed in an eighth part of the time which was required to destroy the logwood purple, and the yellows with tin; neither of which could have been exposed to the sun and air for a single week, without becoming of a faded brown. It is also worthy of observation, that the Tyrian, or shell purple, was destroyed by the oxy-muriatic acid, almost as soon as the logwood purple and quercitron yellows last mentioned, though it would have resisted the sun and air, probably fifty times longer than either of them.

The property by which certain matters decompose solar light, reflecting or transmitting some, and absorbing other rays, so as to produce the sensations or perceptions of particular colours, often depends upon precise, and nice proportions in the constituent parts of these colouring matters, which proportions may be altered, and the colours resulting from them destroyed or changed by various means, acting even in opposite ways.

Oxygene from its ubiquity, as a part of the atmosphere, and its powerful agencies, co-operates in almost all the changes which take place on, or above the surface of the earth, and especially in those connected with either the production or the destruction of colours, and its presence as a *constituent part* of colouring matters, seems to be essentially necessary to those peculiar attractions, or affinities,

which, by their effects upon the rays of light, occasion the perceptions or sensations of colour. This will be abundantly proved, and elucidated by the highly instructing and interesting facts to be stated hereafter, concerning indigo.

But though combinations of oxygene in certain proportions, are necessary to the existence of most, if not of all, colours, an *excess* of it may obstruct all manifestation or appearance of colour, as completely as the *total absence* of it does, in regard to indigo. Of this a *signal* instance, and illustration, will be found hereafter, in the colourable matter of the Buccinum, producing the ancient or shell purple; and this last, as I have already intimated, will moreover afford a most curious demonstration, and exemplification, of the influence of solar light, in one, and that the most common of the ways, in which it acts upon colouring matters; I mean that of separating or causing an abstraction of their oxygene: and it will be readily perceived that these *colourable* matters (of indigo, and of the shell purple,) become the more interesting and instructive, by reason of their *opposite* conditions and analogies.

To ascertain by well-directed experiments, made upon the several dying drugs, and the colours produced by them, with their usual or most suitable mordants, or bases, in which of the ways lately mentioned, or in what other

ways, their several colours are most liable to suffer injuries or decays, would doubtless contribute greatly to improve the art of dying, by enabling us to employ the means proper for obviating or correcting their respective defects, so as to render colours permanent, which have hitherto been deemed fugitive; and, perhaps, increase the durability and beauty, even of those which are considered as permanent.

With this persuasion I have, at different times, projected various experiments, calculated to ascertain the effects of the sun's rays, upon colouring matters, in all their usual combinations, when placed *in vacuo,* and also when immersed in the several kinds of air, and in alcohol, unctuous, and essential oils, diluted acids, and alkalies, in order to ascertain the effects of these different agents or applications, upon the several colours; and also as far as might be practicable, to discover what each had either lost or gained by such treatment. But from the number and variety of my other unavoidable avocations, and interruptions, my progress in these experiments (excepting a few which will be mentioned in their proper places) has not been sufficient to warrant those *ultimate* conclusions, which could only be safely and properly drawn, after an examination and comparison of the *whole* ; and as I may not live or find leisure to execute the whole, I can only recommend the

subject to those who may have sufficient time and qualifications for a due investigation of it.

Until further discoveries, therefore, shall have been made, I consider myself as only authorized to conclude, that the *permanent* colours of matter do not depend upon the thicknesses, sizes, or densities of its parts or particles, but upon certain affinities or attractions, physical, or chymical, by which it is disposed and enabled to absorb and conceal some of the rays of light, and to reflect or transmit other rays, producing the sensations or perceptions of particular colours; and that to the existence or energy of these affinites, or attractions, certain portions of oxygene are generally necessary, as a constituent part of colouring matters; and these portions may in some instances be increased, and in others diminished, by the influence of *radiant matter*, or solar light, which may thereby contribute to the production of some, and the destruction of other colours.

Should I be desired to assign a reason or cause for these affinities, and their connection with particular proportions of oxygene, I can only answer with M. de Buffon, that they who require the reason of a *general effect*, do not consider the infinite extent of nature's operations, nor the confined limits of human understanding.

CHAPTER II.

Of the Composition and Structure of the Fibres of Wool, Silk, Cotton, and Linen.

"Ubi natura desinit nobis incipiendum."

Before I treat of the communication or production of colours by dying or calico printing, it will be proper to inquire concerning the particular natures and differences of wool, silk, cotton, and linen, upon which these operations are usually performed. The two first are animal, and the latter are vegetable substances, differing from each other in their constituent parts and chymical properties, as well as in structure and organization. M. Berthollet has greatly contributed towards ascertaining their *chymical* differences, which seem principally to depend upon a much larger proportion of nitrogene, and also of hydrogene, in the animal, than in the vegetable matters: and as the nitrogene and hydrogene readily assume an elastic form, the wool, hair, and silk, in which they abound, have less adhesion between their constituent parts, than that which exists between those of cotton, and linen, and they are, therefore, more strongly disposed, than the latter, to combine with other substances, when brought into contact with them; and it is, I believe, partly in consequence of this disposition that

wool, hair, and silk, manifest stronger affinities or attractions for colouring matters generally, than cotton, and linen.* They are also more ready decomposed, or injured by acids, alkalies, and other chymical agents, which ought therefore to be very sparingly used in the dying of animal substances: it being found that the sulphuric, nitric, and muriatic acids readily *decompose* wool, hair, and silk, and at the same time destroy, or greatly weaken the texture and connexion of their several fibres; and that alkalies prove equally injurious, *by combining* with them: though silk is indeed not so liable to be acted upon in these ways, because it partakes in some degree of the vegetable nature. Animal fibres, also, contain more oil and less of the basis of charcoal than the vegetable.

It is from the superior chymical affinities, or attractions existing in wool, hair, and silk, for

* *e. g.* Cotton and linen will neither of them receive any colour by the same preparation, and in the same liquor, which dyes wool or woollen cloth scarlet. This is every day seen by the cotton edges with which some sorts of cloth are wove, which remain white after the rest of the cloth is become scarlet. M. Dufay caused a piece of cloth to be manufactured, of which the chain was wool, and the woof cotton. This was afterwards fulled, that both might be brought into a similar state of preparation; and the cloth being then dyed by the usual process, the woollen threads contained in it received a good scarlet, whilst the cotton remained white.

colouring matters, that the facilities with which these substances receive, and permanently retain colours, principally result; though something is doubtless to be ascribed to the differences of conformation, existing between their fibres and those of cotton and linen, which I shall notice under their several heads.

Article I.—*Of Wool.*

The value of this substance, and its fitness for the different kinds of manufacture, depend in a great degree on the length and fineness of its fibres; of which ample information may be found in a Memoir written by M. d'Aubenton, and printed among those of the Royal Academy of Sciences, for the year 1779. Wool is liable to great variations in quality, not only from differences in each particular race or breed of the sheep, from which it is taken, but also of the parts of the body to which it has adhered; that which covers the tails, thighs, and bellies, being always coarser, and less susceptible of receiving colours by dying. It also frequently suffers in quality, and in colour, by the diseases to which sheep are liable; the most healthy of the same flock, always affording wool which is of a better quality than that of the unhealthy; and which has also a greater affinity for colouring matters, and imbibes them more copiously by dying.

Wool is naturally covered by an unctuous substance, which probably is destined to secure it from the injurious effects of moisture. This substance (called *yolk* by the English, and *suint* by the French,) appears, by the experiments of M. Vauquelin, (Ann. de Chim. tom. xlvii. p. 276.) to consist principally of a sort of animal soap, (having potash for its basis,) a greasy matter resembling suet, and a portion of lime in combination with the carbonic, acetic, and muriatic acids.

To prepare wool for dying, this yolk is commonly removed, by scowering, or maceration for a quarter of an hour, in warm water, mixed with a fourth part of stale urine; stirring the wool frequently by sticks, and afterwards rincing it thoroughly, if practicable, in running water. M. Vauquelin, however, thinks it may be advantageous, after wool has been cleansed from every thing which clean water can remove, to soak it for a few hours, *not* in diluted stale urine, but in a *tepid* solution of soap, employing one pound of the latter, with a sufficient quantity of water, to every twenty pounds of wool to be scowered. M. Roard, director of the dying department of the French Imperial manufactories, thinks, that one pound of Flanders soap employed in this way, is sufficient for thirty pounds of wool; but instead of a tepid solution he recommends one that is heated; though not

above 60° of Reaumur; equal to about 160° of Fahrenheit.* He also recommends the spinning of wool in the yolk, and scowering it afterwards; when he says, it will become much whiter than if scowered before the spinning. Another advantage results from postponing this scowering, which is that of preserving the wool from the depredations of moths, and other insects, so long as it retains the yolk; an effect which Reaumur observed, and published in the year 1738. (See Mem. de L'Acad. Re. des Sciences for that year.) The wool of healthy sheep is always more copiously provided with yolk than that of the sickly.

When wool has been spun and wove, it commonly undergoes the operation of *fulling*, which I shall notice, because it depends upon such a *peculiarity* in the structures of its fibres, as seems to increase its fitness to imbibe and retain colours by dying. Fulling, according to

* M. Berthollet, in the last edition of his Elements, tom. i. p. 175, appears to think, that the substitution of soap for the ammonia contained in stale urine, has not been found advantageous in the trials made with it: M. Chaptal, however, in the ivth vol. of his h ymie Appliquée aux Arts, p. 423, treating of this operation, says, that in Spain, and recently in France, cloths have been scowered without either stale urine, or soap, by preserving the water impregnated with the *yolk*, resulting from one operation, and employing it for a second; and that of the second, for a third, &c. until it becomes so thick, and overcharged with yolk, as to be unfit for use.

Sir William Petty (see Spratt's History of the Royal Society,) "is making the cloth to become thicker, with the diminution of its other dimensions, and the covering of its threads, so as that the cloth shall seem to be translated from the likeness of a *tela*, (all of whose threads appear) to that of a *hat*, which has no threads at all; for, by the way, the making of a hat (continues he) is the making of a tela, without spinning or weaving, by a kind of fulling." "This thickening," he adds, "is made by the shortening of threads;" an effect which he erroneously ascribed to the heat of the mill, and the supposed *astringent* operation of urine, fullers' earth, &c.

M. Monge has, however, lately given a better account of the operations of felting and fulling, (see Ann. de Chymie, tom. vi. p. 300, &c.) by which it appears, that the "shortening of threads" is not produced by heat, or by any astringent power whatever, but an effect resulting from the external conformation of the fibres of wool, fur, &c. which appear to be formed, either of small lamina placed over each other in a slanting direction, from the root towards the end or point of each fibre, like the scales of fish, lying one over the other, in succession, from the head to the tail; or of zones, placed one upon another, as in the horns of animals; from which structure each fibre, if drawn from

its root towards the point, will pass smoothly through the fingers; but if it be drawn in a contrary direction, from the point towards the root, a sensible resistance, and tremulous motion will be felt by the fingers. This conformation disposes the fibres of wool to catch hold of each other, and as they cannot recede, when acted upon by other bodies, they naturally advance, by a progressive motion, towards, and beside each other, from the end towards the root; a disposition which is very inconvenient to spinning, and therefore the wool is greased, that the asperities arising from this structure of its fibres may be thereby covered, or sheathed, as a covering of oil sheathes those of a file. But the wool being manufactured, and the grease no longer useful, it is removed by scowering, not only for the sake of cleanliness, but that it may not frustrate the process of dying. The cloth is therefore carried to the fulling mill, and there subjected to the action of large beetles, with fullers' earth and water, by which the cloth is not only scowered, but its fibres, in consequence of the structure just described, being made to conjoin, and advance toward, and beside each other, become shorter, and more closely connected, or felted together, the warp and woof losing in extent, but gaining proportionably in thickness.

The lamina, or zones, under consideration,

afford many interstices in the fibres of wool, suited to receive and contain the particles of colouring matters, when applied to them in the operation of dying; but these interstices being small, and the fibres of the wood naturally elastic, no colour can be conveyed into these cavities, until they are dilated by hot or boiling water; whereas silk, cotton, and linen, are made to receive colours without heat, as permanently as with it. And this difference manifestly arises from the smallness of the interstices in which the colouring particles are deposited in the fibres of wool, and their elasticity; and as the colouring particles are only made to enter and deposit themselves by an artificial dilatation, it follows that, when this ceases, the filaments will again contract to their former size, *upon* the colouring matters so introduced, and hold them much more strongly than they are likely to be held in other substances, whose interstices are large enough to receive colouring particles without being dilated, and which, therefore, cannot be supposed ever to contract and compress them in the same way: and this difference, joined to the superior chymical attraction of animal fibres for colouring matters, will sufficiently explain why many colours dyed upon wool prove so much more durable than upon cotton or linen. Wool, when dyed in the fleece, takes up much more colouring matter than when spun, and much more

than when wove into cloth. It is also more or less penetrated, according to the fineness of its own texture, and the particular nature of the colouring matter with which it is dyed: the very finest cloth is never *thoroughly* dyed scarlet, it being always found white within when cut.*

Wool taken from different breeds of sheep, in various countries, is naturally of different colours; as white, yellow, reddish, and black. Formerly, all the flocks in Spain, excepting those of Andalusia, were of this *last* colour, it having been preferred for wearing by the Spaniards; and this natural (brownish) black is even at this time manufactured, and worn constantly by some religious orders in Roman Catholic countries. The white wool, however, is now almost universally preferred to every other, as being susceptible of receiving even a better black by dying, than any which is natural. The cloth worn by *Martial*, appears to have received none but the *natural* colour of the wool, whatever that may have been. He says (xiv. 133)

* The late Mr. Nash, and his successor, Mr. Dymock, in Gloucestershire, by causing broad cloths to be wove of threads but *little twisted* in the spinning, have succeeded in making their scarlet dye penetrate farther into the cloth than would otherwise have been practicable; perhaps also this difference of twisting may contribute to the remarkable beauty of their scarlets, by an alternation in the affinity of light.

> "Non est lana mihi mendax, nec mutor ævo
> ——————me mea tinxit ovis.

And Virgil, in predicting the auspicious events which were supposed by him to follow the birth of Marcellus, (nephew to Augustus) mentions the sheep as *naturally* producing wool, of the richest and most brilliant colours.

> "Nec varios discet mentiri lana colores:
> Ipse sed in pratis aries jam suave rubenti
> Murice, jam croceo mutabit vellera luto.
> Sponte sua sandyx, pascentes vestiet agnos."
>
> Eclogue iv.

The lutum of the third of these lines appears to have been the Reseda luteola, or weld plant, now used as a yellow dye, and it has been conjectured by professor Beckman, that the *Sandyx* of the last line, which is represented as giving a *red* colour to the wool of the lambs feeding upon it, must have been the madder, which is known to have grown *wild* in many parts of Italy. Its leaves are said to impart a reddish colour to the milk of cows, when eaten by them, and the roots, notoriously stain the bones of hogs of a bright red, when they make part of the food of these animals.

Article II.—*Of Silk.*

This consists of the fine threads composing the follicle of the Pupa, of the Bombyx Mori,

a Moth or Phalena belonging to Linneus's third order of insects. (Lepidoptera.)

It has been said and believed, that silk was exclusively produced in *China*, until the reign of the Greek Emperor Justinian. But of this there is no sufficient evidence. Pliny, indeed, after describing the countries inhabited by the Scythians, mentions the *Seres* as being the first or nearest civilized people beyond those regions; and he adds, that they were famous for the fine wool *combed from* their trees, of which he gives some account, so indistinct, however, that we may doubt whether it does not relate to cotton, rather than to silk.* But there is a passage much less equivocal in his eleventh book, (Chap. 22,) where he mentions a kind of insects, greater than the wasps and hornets which he had just before described, and to which he gives the generic name of Bombyx, adding that they are produced in *Assyria*; and after a fabulous account of the nests and honey, which he supposed them to make like bees, he says, they engender in a different manner; i. e. from worms which put forth two horns; that these are *Erucæ*, and afterwards

* "Primi sunt hominum, qui noscantur, *Seres*, lanicio sylvarum nobiles, perfusam aqua depectentes frondium canitiem: unde geminus fœminis nostris labor, redordiendi fila, rursumque texendi. Tam multiplici opere, tam longinquo orbe petitur, ut in publico matrona transluceat." Lib. vi. cap. 17.

change to Bombylii, then to Necydali; whence, after six months, they become Bombyces, spinning and weaving webs like those of spiders, to make garments for luxurious women, which (garments) are called Bombycina. He adds that the first who found means to unweave these webs, and weave them again, was a female of *Cos*, named Pamphila, the daughter of Latous, who ought not to be defrauded of the honour of inventing a species of clothing, through which women may expose their beauties, as if they were naked.*

Though this account is manifestly incorrect, as well as imperfect, there can be no doubt of Pliny's intention to describe the moth of the silk worm, and its passage through the larva and pupa states; but I do not think that in his time the Romans always distinguished silk from cotton, as the terms bombyx, bombycina, and sericum, were sometimes applied to muslin and other cotton cloths, as well as to those of silk, and indeed the garments which Pliny, in his next chapter, mentions as being made of the

* "Et alia horum origo e grandiore vermiculo, gemina protendens sui generis cornua: hi erucæ sunt: fit deinde, quod vocatur Bombylius: ex eo Necydalus, ex hoc in sex mensibus Bombyx. Telas araneorum modo texunt ad vestem luxumque fæminarum quæ bombycina appellatur. Prima eas redordiri, rursusque texere invenit in *Ceo* mulier Pamphila Latoi filia, non fraudanda gloria excogitatæ rationis, ut *denudet* fœminas vestis."

silk produced by the Bombyx of *Cos*, (which he represents as different from the *Assyrian*,) must have been cotton. *These*, he says, even the men were not *ashamed* to wear in the *summer*, when, contrary to ancient manners, they thought *themselves overloaded* by any other than light *clothing*. He adds, however, that the men had not in his time begun to wear the *Assyrian* silk, but had left it to adorn females exclusively. "Nec puduit has vestes usurpare etiam viros, levitatem propter æstivam: in tantum a lorica gerenda discessere mores, ut oneri sint etiam vestes: *Assyria tamen bombyce adhuc fœminis cedimus.*"

It seems difficult to ascertain what nation Pliny intended to describe under the name of *Seres*, there being no proof that in his time the Romans had ever heard of China; though we have good reason to believe, that the manufacture and use of silk were introduced among the Chinese at a very remote period. We are indeed informed, that the annals of China mention the wife of an emperor, named Hoagti, as the first person who employed herself in spinning silk, produced by silk worms in their wild or natural state. But this was probably done as soon in other countries, and especially in Persia, where both the white and black mulberry trees were indigenous. Mr. Colebrooke informs us, that in the *most ancient Sanscrit* books there is frequent men-

tion, not only of silk, *but of an Indian class, whose occupation was to attend silk worms.* See Asiatic Researches, vol. v.

It is indeed probable, that the very small portion of silk which had found its way to Rome, in or before Pliny's time, came not from China, but Persia; whence the Greeks, who returned from the army of Alexander the Great, appear to have first brought wrought silk into Greece, about 223 years before the Christian Æra: and the emperor Heliogabalus is said to have been the first person who, about 440 years afterwards, wore a *Holosericum*, or garment composed entirely of silk, which commodity was then rarely sold for less than its weight in gold: and it is related, I think, by Nopiscus, that the emperor Aurelian resisted the earnest solicitations of his empress, for a robe of silk, as being too costly.

But about the year 550, two monks brought from India to Constantinople a quantity of the eggs of the bombyx mori, which they had carefully deposited in hollow canes; and the eggs being hatched by the warmth of a dunghill, and the larvæ fed on the leaves of wild mulberry trees, the insects, under the protection of the emperor Justinian, were rapidly multiplied in the Peloponnesus, and other parts of Greece;* whence they were afterwards carried to Sicily, and several parts of Italy. In the 13th

* See Procopius, Lib. iv. Cap. 17, de Bello Gothico.

century, the Venetians established very extensive manufactories of silk, in their territories, as did the Florentines in the next century. Afterwards, the Moors introduced silk worms, and the manufacture of silk, into the southern parts of Spain, particularly Murcia, Grenada, and Cordova, whence silk stockings were brought over to our Henry the 8th, and Edward the 6th. Henry the 2d of France, is said to have been the first person, who wore silk stockings in that kingdom, (at the marriage of his daughter, and that of his sister ;) and we are told, that a pair of black silk stockings, having been presented to Queen Elizabeth, she was highly pleased with them, and resolved never afterwards to wear any other, than silk stockings.

Though the silk of the *Bombyx mori,* greatly excels that of other moths, by its abundance, pliability, and brilliancy, as well as the facility with which it may be reeled, it is not the only production of this kind, capable of being made useful to mankind.

The Phalèna Atlas Lin. produces in China very large cocoons, and their silk is remarkably strong, but being difficult to reel it is commonly spun.

The Phalena Cynthia, (or *Arrindy* silk worm,) also, is a beautiful moth, of which the natives of the interior, north-eastern part of Bengal, breed great numbers, as they do of the common

silk worm, in a *domestic* state. Its caterpillar is very large, and feeds voraciously on the leaves of the common Ricinus, or Palma Christi. The cocoons of this moth, according to Dr. Roxburgh, " are remarkably soft and white, or yellowish, but the filaments are so exceedingly delicate, as to render it impracticable to wind off the silk : it is therefore spun like cotton. The yarn thus manufactured, is wove into a coarse kind of white cloth, of a seemingly loose texture, but of *incredible durability;* the life of one person, being seldom sufficient to wear out a garment of it; so that the same piece, descends from mother to daughter." It must, however, be washed only in cold water, for if put into that which is boiling, it will " tear like old rotton cloth.

Dr. Roxburgh also describes another silk worm, the Tussach, or Phalena Paphia, which is " found in such abundance over many parts of Bengal, and the adjoining provinces, as to have afforded to the natives, from time immemorial, an abundant supply of a most *durable* coarse dark-coloured silk, commonly called Tussach silk, which is woven into a kind of cloth, called Tussach doot'hies, much worn by Bramins and other sects in India." This cloth, as the doctor thinks, might " be highly useful to the inhabitants of many parts of America, and the south of Europe, where a *cheap*, light, cool,

durable dress, such as this silk makes, is much wanted." See the Transactions of the Linnæan society, Vol. p. 33, &c.

Silk is naturally covered with a kind of varnish, or gummy substance; and almost the whole of that known in Europe, is moreover tinged of a yellow colour, which, for most purposes, it is necessary to remove, as well as the varnish. This is commonly done by submitting it to the action of soap, in circumstances which M. Berthollet has described, as well as some other means for answering this double purpose. (Tom. i. p. 184, &c.)

M. Roard, (director of the Imperial French dyes, at the Gobelins) has lately ascertained, that besides the gummy and colouring matters, there is a substance, much like wax, to be removed in this operation, (decreusage.) He states the gummy matter, as commonly amounting to twenty-three or twenty-four per cent. of the silk, and to be soluble in water: and the colouring matter to make about a 55th, or 60th part of the silk. It is very soluble in alcohol, but not in water. The wax seldom exceeds the hundreth part of the silk, and is often not more than half so much. All these matters may, he thinks, be removed with better effect, by soap than by soda: and as silk by long boiling, after it has been made white, often becomes yellow again, and is moreover hurt in its texture, M.

Roard thinks, that instead of employing the soap *partially*, or at different times, as has been frequently practised, it is best *at once* to employ the whole quantity likely to be wanted, and thereby shorten the time of boiling to an hour, or an hour and one half; which will commonly suffice, and leave the silk with more of its natural lustre, and greater softness; as well as strength. M. Roard, indeed, thinks, that when silk is to be dyed of a crimson, or any other colour, to which its natural yellow would not prove unsuitable, it is best not to remove the *latter* completely, because, when this is done, the dyed colour is commonly found to have less brilliancy, than it would otherwise have had.

When silk has been freed from both its gummy varnish, and its yellow colour, it is sometimes necessary to whiten it still farther, by the fumes of sulphur applied to it, and confined in a stove. But though sulphureous acid gas, applied in this way, readily whitens the silk, and thereby renders it more fit to exhibit lively colours, a portion of sulphur adheres to it, which, when it is intended to be dyed, must be removed by soaking and agitation, for a considerable time, in warm water, that it may not tarnish the colours; an effect which sulphur generally produces, to those of wool and silk. The lustre so much desired, in colours dyed upon silk, seems, in a great degree, to depend upon its smooth glossy

surface, which acids, alkalies, and other chymical agents (particularly the solutions or oxides of tin), contribute to impair, and are therefore to be sparingly used.

Silk, in its disposition to receive, and retain colours for dying, seems to partake of a middle nature, between that of the animal and vegetable substances: by its abundance of nitrogene, and hydrogene, it possesses, like wool, a strong attraction for colouring matters; but its fibres having neither a similar organization, nor an equal degree of elasticity, it is capable of imbibing colours, like linen and cotton, without any previous dilatation of its pores by hot water, but, like them, it parts with colours, so imbibed, the more easily, in consequence of this natural openness, or the want of contraction, in its pores; though, upon the whole, colours dyed in silk are more lasting, than when dyed in linen and cotton, on account of its greater affinity with colouring matters, which seems to result from its animal nature.

In the year 1709, Mr. Bon, First President of the Chambre des Comptes, aides, & finances, at Montpellier, communicated to the Royal Society of that city, a discovery which he had made of a new kind of silk, from the very fine threads, with which several species of spiders entwine their eggs; which threads were found to be much stronger than those composing the

spider's web. They were easily separated, carded, and spun, and then afforded a much finer and stronger thread than that of the common silk, though somewhat less glossy. They were also found capable of receiving all the different dyes, with equal facility. Three ounces of this new silk, made a pair of durable stockings of the largest size; and as the spiders were much more prolific, and much more hardy than the silk worms, great expectations were formed, of benefit from this discovery. M. Reaumur, therefore, took up, and prosecuted the inquiry with zeal. He conceived that, when spiders were artificially multiplied for the production of silk, it would be impossible to provide them sufficiently with flies, their natural food. This obstacle, however, was soon removed, by his finding that they would subsist very well, upon earth worms chopped, and upon the soft ends or roots of feathers. But a new obstacle arose from their unsocial propensities, which proved insurmountable; for though at first they seemed to feed quietly, and even work together, several of them at the same web, yet they soon began to quarrel, and the strongest devoured the weakest, so that of two or three hundred, placed together in a box, but three or four remained alive after a few days; and nobody could propose to keep and feed each separately. M. Reaumur found their silk to be naturally of different colours; particularly white, yellow,

sky blue, grey, and coffee-coloured brown. See Hist. & Mem. de l'Acad. Royale des Sciences, ann. 1710. See also a Dissertation by M. Bon, "sur l'utilité de la soye des Arraignées." 8vo.

Article III.—*Of Cotton.*

This is the well known production of a genus of plants, denominated *Gossypium;* of which Linneus has described five species, viz. G. herbaceum, G. arboreum, G. hirsutum, G. religiosum, and G. Barbadense. To these, five other species have been added, partly indeed by elevating to the rank of distinct species, several which had previously been considered as merely varieties of some of the former. This addition consists of of G. Indicum, G.micranthum, G. vitifolium, G. latifolium, and G. peruvianum. But as the specific characters of these several species are not connected with the subject of dying, or calico printing, a particular account of them would be here superfluous. The fibres of cotton differ not only in their length, fineness, and strength, but also in their colours.

Most of the species of Gossipium, produce cotton which is naturally white, though a few produce it of other colours, of which that called *Nankin* by the English, and "coton a couleur *rousse* (de Siam)," by the French, is best known. Von Rohr, who was employed by the Danish government as a botanist, during ten years, in

the West Indies, has described three species of this *Nankin* cotton,* which he distinguishes chiefly by peculiarities in their respective seeds.

Cotton of this colour has been long cultivated in China, and more especially along the sea shores of the south-eastern part of the province of Kiang-nam, of which Nankin is the capital, as it formerly was of the Chinese empire. It is also now cultivated at Malta, and in some of the West India islands, and is said to grow naturally in Africa. It is asserted, that a species of cotton, naturally of a *bright yellow* colour, is produced in *Dahomy*, but that the exportation of it is prohibited, by the government of that part of Africa. Mr. Clarkson has mentioned a species of cotton, naturally of a *crimson* colour, as also growing in Africa, particularly in the *Eyeo* country; of which a small specimen, was brought to Great Britain in the year 1786. He adds, that "the value of this cotton would be great, both to the importer and to the manufacturer of muslins;" that "the former would immediately receive eight shillings the pound for it, and the latter would gain considerably more by his ingenuity and taste."

Lieutenant Matthews also, in describing the several species of cotton produced at Sierra Leone,

* See "Anmerkungen ueber den Cattunbau, zum nuzon der Daenischen Westindischen Colonien, &c. von J. P. B. Von Rohr. Altona, 1793. 2 vols. 12mo.

mentions one, of a pale red or pink colour: and the late Mr. Bryan Edwards, in his History of the West Indies, (vol. iii. p. 199, 8vo.) mentions, as growing wild in the Spanish part of St. Domingo, "a species of cotton of which the wool is *reddish*."

Cotton offers to the industry and wants of mankind a filaceous substance, which, without the tedious artificial preparation required for hemp and flax, has, during many ages, especially in warm climates, constituted the most useful, as well as ornamental and graceful parts of their clothing. Whatever obscurity or uncertainty there may be in some parts of Pliny's History, relating either to silk or cotton, there is but little of either, in his account of the cotton of Upper Egypt,* growing on a *shrub*, which some (says he) call Gossipium, others Xylon, and the cloth made of its wool, Xylina. It is but small, and produces a fruit resembling the bearded nut, (filberd) from whose interior capsule, a fine wool is spun, which no linen can excel in softness and whiteness. Of this, he adds, are made those *sacerdotal* garments, in which the Priests of Egypt greatly delight.

* "Superior pars Ægypti in Arabiam vergens, gignit fruticem, quem aliqui Gossipion vocant, plures Xylon, et ideo lina inde facta Xylina. Parvus est, similemque barbatæ nucis defert fructum, cujus ex interiore bombyce lanugo netur: nec lina sunt ei candore mollitiave preferenda. Vestes inde Sacerdotibus Ægypti gratissimæ." Lib. xix. cap. i.

Vossius thinks Gossippion, or Gossypium, to have been an Egyptian word; the Greek name of cotton (Xylon) was abbreviated from Eryxylon, which signified *tree wool;* and the German, Dutch, Swedish, and Danish names of cotton, have this signification. The Arabian name is *cotum*; and the English and French, probably, became acquainted with it, by joining in what were called the Holy wars, and changed it to *cotton,* and *coton.* The Italians also borrowed their name of cotone from the Arabs, and their other name of bombagia, from that of bombax, one of the names, by which the Latins designated the wool-bearing trees, "*arbores lanigeræ*" of Pliny, who, in his twelfth book, chapter 3, notices a *second* time, these *wool-bearing* trees in the country of the *Seres*; but so ambiguously, that I cannot help wondering, how it should have been so generally believed, that the Seres were Chinese, and that silk, rather than cotton, was in Pliny's contemplation, when he mentioned the wool of their trees.* The important benefits derived to mankind from the different

* Mr. Barrow, in a note to p. 436, of his travels in China, makes the following observation, "Ptolomy the geographer, places *Serica,* adjoining to Scythia *extra Imaum,* corresponding with Cashgar, Tangut, and Kitai, countries famous for the cultivation of the cotton plant. It would seem, indeed, from all the passages which occur in ancient authors, concerning the *Seres,* that cotton was the substance alluded to, rather than silk,

species of cotton shrubs, have caused them to be cultivated more extensively perhaps than any other vegetable. In China, it is planted from Canton to Pekin, and from the western shores of that empire, to the deserts adjoining to Hindostan; and also along the coasts of the two Indian Peninsulas, with those of Arabia, and throughout the Mogul empire, and the innumerable islands of the Indian ocean. It appears to have been known from the remotest times, of which we have any account, in Persia, Hindostan, Egypt, and Æthiopia;* and was found, also, by Columbus, and succeeding adventurers to America, in all the intertropical coasts and islands of that continent. Its introduction to Greece, Malta, Sicily, Apulia, and Spain, was probably effected by the Saracens.

Such quotations might be multiplied, but I have given more than enough of them.

The structure of the fibres of cotton has not

and that these people were not the present Chinese, but the Tartars of Kitai."

* Herodotus, Lib. iii. 106, when writing of India, mentions trees growing wild, and instead of fruit, bearing a sort of wool, finer and better than that of sheep; and he adds, that the Indians clothed themselves with wool gathered from these trees. Arrian, also, on the authority of Nearchus, says, the Indians clothe themselves with linen produced upon trees: and Virgil mentions the

——" Nemora Æthiopum molli canentia lana."

GEORG. ii. v. 120.

been well ascertained. Lewenhoeck, by microscopical examinations, found each of them to have two sharp sides; and it seems to be owing to this circumstance, or to their possessing some asperities like the filaments of wool, that cotton greatly irritates and inflames wounds, ulcers, &c. if applied to them instead of lint, from which they differ totally in this respect; and perhaps the particular structure which occasions this difference, also occasions some in the conformation and number of their pores, to which we may probably ascribe the disposition which cotton manifests, to admit and retain colours better than linen, though not so well as wool and silk, because its vegetable nature does not afford it equal attraction for colouring matters.

M. le Pileur d'Apligny endeavoured to explain the cause, why colours are less durable when dyed in silk, cotton, and linen, than in wool, by supposing that the pores of the three first of these substances, were smaller than those of wool; and that therefore colouring particles could not enter into them so easily, and freely as into those of wool. But the very reverse of this supposition seems true, there being little difficulty in making silk, cotton, or linen, imbibe colours, even when topically applied cold, without any artificial dilatation of their pores, which is necessary in the dying of wool. The real difficulty, therefore, is not in making them im-

bibe, but in making them retain, the colouring particles when imbibed; because, being admitted so readily, into their undilated pores, they cannot be afterwards compressed, and held therein, by any contraction of these pores, as is done in those of wool. We know that it requires twice as much cochineal, to produce a crimson on silk, as on wool; which is a proof that it can take up a greater quantity, and consequently that its pores are at least sufficiently large, and accessible: we know also, that unbleached cotton is always preferred for dying the Turkey red, it being found to retain the colour most permanently; doubtless, because its pores, or interstices are less open before, than after the operation of bleaching. This is also the case of raw or unscoured silk, which, as the ingenious Mr. Henry of Manchester, observes, is "more easily and permanently dyed, than that which has passed the above described process," of whitening and scouring: and, indeed, the openness of the pores of cotton and linen, and their consequent readiness to imbibe, both colouring particles, and the earthy or metallic bases employed to fix most of them, are circumstances upon which the art of calico printing is in a great degree founded. To prepare and dispose cotton for receiving colours by dying; it is commonly boiled, in a very diluted solution of vegetable or fossil alkali, for about two hours,

and afterwards rinced in clean running water; and for calico printing, it is soaked in water, acidulated with about one-fiftieth of its weight of sulphuric acid, and afterwards rinced thoroughly in a clear stream of water. Cotton bears the action of acids much better than either wool or linen.

Concerning flax, and its conversion to linen, so much has been written, both by ancient and modern authors, and its preparation for dying, so nearly resembles that of cotton, that I may hope to be excused, for not discussing this subject.

CHAPTER. III.

Of the different Kinds and Properties of colouring Matter, employed in Dying, Calico Printing, &c.

"Toutes les choses visibles se distinguent ou se rendent "desirable par la couleur."

COLBERT. *Instruction general pour la Teinture, &c.*

By colouring matter, I understand a substance which possesses, or acquires a power of acting upon the rays of light, so as either to absorb them all, and produce the sensation of black; or only to absorb particular rays, and transmit or reflect others, and thereby produce the perception of that particular colour, which belongs to the ray or rays so transmitted or reflected.

Among minerals, the colouring matter of each is commonly distributed equally to all its parts; but in animal and vegetable substances, it generally exists in particular parts, or particles, which are capable of being extracted and collected for the purposes of dying, &c.

Colouring matters possess peculiar chemical properties, which distinguish them from all other kinds of matter; for besides their several affinities with particular rays of light, they have others which render them susceptible of being acted upon, and modified by a variety of chemical agents, as well as of forming permanent

combinations with the filaments of wool, silk, cotton, linen, &c. But in respect of these affinities, colouring matters also differ essentially from each other, and must therefore be applied in different ways, and with very different means, to produce permanent colours in other matters. The art of dying is founded upon a knowledge of the particular properties and affinities of these matters, not only as far as they relate to the substances intended to be dyed, but also as far as they are connected with the operations of other agents, by which they are liable to be acted upon, either during the process of dying, or afterwards.

Many species of animal and vegetable colouring matters, suffer nearly similar changes from the action of acids, alkalies, and other chemical agents; from which it may be presumed, that there is something of a common, or similar nature, in the constitution of many of them. But though it would be highly useful to establish general principles and conclusions on this subject, we are not yet furnished with the necessary facts; and whilst this continues to be the case, it will be best to wait, or rather seek, for more knowledge, and avoid fallacious suppositions or explanations.

Sir Isaac Newton supposed coloured matters to reflect the rays of light; some bodies reflecting the more, others the less refrangible

rays most copiously; and this he conceived to be the true, and the only reason of their colours. Mr. Delaval, however, has lately maintained (in the 2d. vol. of the Memoirs of the Philosophical and Literary Society of Manchester,) "that, in transparent coloured substances, the colouring matter does not reflect any light; and that when, by intercepting the light which was transmitted, it is hindered from passing through substances, they do not vary from their former colour to any other colour, but become entirely black:" and he instances a considerable number of coloured liquors, none of them endued with reflective powers, which, when seen by *transmitted* light, appeared severally in their true colours; but all of them, when seen by *incident* light, appeared black: which is also the case of black cherries, black currants, blackberries, &c. the juices of which appear red when spread on a white ground, or otherwise viewed by transmitted, instead of incident light; and he concludes, that bleached linen, cotton, &c. "when dyed or painted with vegetable colours, do not differ in their manner of acting on the rays of light, from natural vegetable bodies; both yielding their colours by transmitting through the transparent coloured matter, the light which is reflected from the white ground:" it being apparent, from different experiments, "that no reflective power

resides in any of their component parts, except in their white matter only," and that "transparent coloured substances, placed in situations by which the transmission of light through them is intercepted, exhibit no colour, but become entirely black."

"The art of dying, therefore (according to Mr. Delaval,) consists principally in covering white substances, from which light is strongly reflected, with transparent coloured media, which, according to their several colours, transmit more or less copiously the several rays reflected from the white substances," since "the transparent media themselves reflect no light; and it is evident that if they yielded their colours by reflecting, instead of transmitting the rays, the whiteness, or colour of the ground on which they are applied, would not in any wise alter or affect the colours which they exhibit."

Having had reason to differ from Mr. Delaval on other points, I am happy in being able to agree with him on this, so far as relates to transparent colouring matters, when applied to wool, silk, &c. without the interposition of any earthy or metallic basis. But when any such opake basis is interposed, the reflection is, doubtless, made principally by it, rather than by the substance of the dyed wool, silk, &c. and more especially when such basis consists of

the white earth of alum, or the white oxide of tin; which, by their strong reflective powers, greatly augment the lustre of colours. There are, moreover, some opake colouring matters, particularly the acetous, and other solutions of iron, used to stain linen, cotton, &c. which must necessarily themselves reflect, instead of transmitting the light by which their colours are made perceptible.

It has been already mentioned, that when the rays of light are separated from each other by the prism, in consequence of their different degrees of refrangibility, they produce a perception of seven distinct colours, with all their intermediate shades; and that these are all equally simple and primitive. There is, however, this peculiar property belonging to the red, yellow, and blue colours, whether prismatic or permanent, that they are incapable of being produced, like all the rest, by the *combination* of any other colours. Blue and red will compose a purple; blue and yellow, a green; red and yellow, an orange, &c.; but none of these, by any composition, will produce either the blue, yellow, or red: these last, therefore, are in all cases *simple* or uncompounded;* but

* Dufay would only admit of three primitive colours, red, blue, and yellow, because with these dyers and painters can readily compound all the others; and a late writer, adopting Dufay's

all the others may be, and in reality are, sometimes simple, and sometimes compounded; and this is true not only of those which are merely prismatic colours, but of those which exist naturally in bodies, or are communicated by painting, dying, &c. Iron, as has been already mentioned, will, by different degrees of oxydation, produce all possible varieties of colour; and these colours will be all simple or uncompounded; and so will the purple of gold, the green of copper, and the other colours found in the several oxides of metals. This is also the case of the violet and purple dyed from logwood; of the green of the leaves, &c. of vegetables; and of the orange dyed from the quercitron bark, as will be hereafter mentioned. And among animal colours, numerous instances may be alleged of simple or uncompounded greens, oranges, purples, and violets: even the yellowish white liquor of the murex, and buccinum, from which the celebrated Tyrian purple was produced, passes quickly through all the shades of yellow, green, violet, and purple, upon being exposed to the sun; and these must necessarily be deemed simple, not compound colours. But on the other hand, dyers, painters,

opinion on this subject, says, the colours of the prism are immaterial, accidental, and artificial. But those of the dyer and painter are substantial, natural, and palpable.

&c. daily produce orange, green, purple, and violet, by mixtures of the blue, yellow, and red: nor is it necessary that these should be intimately mixed, since cloth woven from a red warp, and a blue woof, will appear to be uniformly purple or violet; or if the warp be yellow instead of red, the cloth will appear *green*, in each case exactly resembling the simple homogeneous colour, which, in the prismatic series, lies between the colours of the warp and woof. It has moreover been repeatedly found in dying compound colours, as for instance, green, that laying a permanent blue over a fugitive yellow, does not defend the latter, or make it in any degree more lasting, but that it will decay (leaving the blue in full strength) as rapidly as if no blue had been applied; and therefore we may presume, that the fibres of the dyed stuff were but partly covered with the yellow colouring matter, and that when the blue came to be afterwards added, its particles found spaces sufficient to lodge themselves collaterally, without being placed upon the yellow particles.

Several attempts have been made to arrange and class the different species of colouring matters employed for dying and calico printing; but none seems to accord with, or give just ideas of, their several natures and properties. M. Berthollet, indeed, alleges sufficient reasons for not dividing these matters, as Mr. Macquer

did, into extractive and resinous, and also for not making their effects depend, as Mr. Pœrner has done, upon the mucilaginous, earthy, saline, resinous, or oily parts of which they were supposed to be compounded, but without proposing any suitable arrangement of his own.

To me, however, colouring matters seem to fall naturally under two general classes; the first including those matters which, when put into a state of solution, may be fixed with all the permanency of which they are susceptible, and made fully to exhibit their colours in or upon the dyed substance, without the interposition of any earthy or metallic basis; and the second, comprehending all those matters which are incapable of being so fixed, and made to display their proper colours, without the mediation of some such basis. The colours of the first class I shall denominate *substantive;* using the term in the same sense in which it was employed by the great Lord Verulam, as denoting a thing solid by, or depending only upon, itself; and colours of the second class I shall call *adjective,* as implying that their lustre and permanency are acquired by their being adjected upon a suitable basis.

Earthy and metallic bases when thus interposed, serve not only as a bond of union, between the colouring matter, and the dyed substance, but they also *modify* (as well as fix)

the colour; some of them, particularly the oxide of tin, and the earth of alum, *exalting* and *giving lustre* to most of the colouring matters, with which they are united; whilst others, and especially the oxide of iron, blacken some, and darken almost all such matters, if made to combine with them.

Substantive colouring matters are but few in number, because a few only of the substances employed in dying, possess such decidedly energetic affinities, as to be able to contract a permanent union with the stuffs to be dyed, merely by being applied to, or brought into contact with them. This is more especially true of *linen* and *cotton;* for in regard to wool, several of the adjective colouring matters, particularly those of Madder, Cochineal, Kermes, and Lac, are so much attracted by it, that with the aid of boiling water they fix themselves in, or to, the fibres of wool, so as to produce colours of some, though less durability, than those which would have been produced if a basis of alumine, or the oxide of tin, had been also applied, and without such basis, these colours never rise so high, or acquire so much lustre as they would have done therewith.

Of substantive colours, I shall first notice the animal, next the vegetable, and, lastly, the mineral.

CHAPTER IV.

Of substantive Animal Colours, and principally of the Tyrian Purple.

——————" Tyrioque ardebat *murice* lana." Virg. Æneid, lib. iv.

" Huic *fasces secures que Romanæ viam faciunt:* idemque pro *majestate* pueritiæ est: distinguit ab equite Curiam: *Diis advocatur placandis;* omnemque vestem illuminat: *in triumphali miscetur auro:* qua propter excusata et *purpuræ* sit insania." Caii Plinii secundi Hist. Lib. ix. cap. 36.

This, during many ages, was the most celebrated, and *venerated* of all the colours given by dying; and among the rich and beautiful, it seems to have been the first which mankind were enabled to fix permanently on wool, and linen. It was obtained from a whitish half-fluid matter, secreted by particular organs in certain *univalvular* shell fish, and retained in an appropriated receptacle, with which they were each naturally provided; though we are completely ignorant of any benefit which this secretion produced to the fish themselves.

There is much obscurity, and some inconsistency in the accounts transmitted by ancient writers of the shell fish, which afforded the purple dye. Those of Pliny are the most copious and intelligible, though they are sometimes at variance with each other. He mentions these fish under the several names of Conchylium, Murex, Purpura, and Buccinum; and these se-

veral names have been also employed by other Latin authors. But Fabius Columna, a noble Neapolitan, who first published figures of plants, from engravings made by his own hand, and wrote a learned dissertation *de purpura*, (printed at Rome in 1616) after much pains employed, to elucidate and reconcile the different passages of ancient writers on this subject, thinks himself warranted to conclude that there were but two kinds or genera of these fish, viz. the purpura and the buccinum: that the term *conchylium*, signified generally all the species of purpuræ, and that it was also used sometimes to signify the purple colour itself; that Pliny employed it in the former sense, in the 41st chapter of his 9th book; and in the latter, in the 36th chapter of the same book, that the term murex, was also used as a generic name for the purpuræ; and consequently that both conchylium, and murex, were synonymous, of the purpura; "quarum alterum a conchis nomen, alterum ab aculeis, qui alio nomine murices dicuntur." I am afraid, however, that Pliny was neither constant nor correct in using these names, even in the ways by which Columna endeavours to render him consistent and intelligible, for in the chapter last quoted, he mentions the purpuræ, and the murices, as being different fish, and compares their respective habits, &c. adding as a peculiarity of the former, " Sed purpuræ florem illum

tingendis expetitum vestibus, in mediis habent faucibus : liquoris hic minimi est *in candida vena*, unde pretiosus ille bibitur nigricantis rosæ colore sublucens." It seems probable that the term murex,* was in this instance erroneously substituted for buccinum ; as he proceeds to state that all the shell fish yielding the purple, or other lighter colours of the conchylia, are *in matter the same*, and differing only in temperament ; that they are of two kinds, (" duo sunt genera") one which is the lesser kind, being called *buccinum*, from its likeness to the horn or cornet, so named and employed to produce sound by blowing through it (" quo sonus editur.") These last he describes as being round at the aperture, with a serrated margin. The other kind, says he, is called *purpura*, and has a projecting pipe-shaped beak (rostrum) with a lateral winding cavity, through which it puts forth its tongue ; the body of the shell is moreover muricated, or armed, even to its upper pointed extremity, with rows of spines, seven in number ; which are wanting in the buccinum. This last, he adds, adheres to rocks and large stones, whence it can alone be collected.

* " Murex cochlea est maris, dicta ab acumine et asperitate quæ alio nomine conchylium nominatur, propter quod circumcisa ferro, lacrymas coloris purpurei emittat, ex quibus purpura tingitur, inde ostrum appellatum," &c. Isidorus, lib. 2. Origin. cap. 6.

In the same chapter, Pliny tells us, that the best purpuræ found in Asia, were those taken in the sea adjoining to Tyre: that in Africa the most esteemed were those of Meninx (Meninge), and the sea coast of Getulia: and in Europe those of Laconica. He adds that the Tyrians, when they caught any of the greater purpuræ, took the fish out of their shells, the better to extract the colouring matter, but that they obtained it from the smaller, by grinding them in mills. That the fishermen endeavoured to take the purple fish alive, because it otherwise ejected and lost its precious liquor, together with its life. But on this point he seems to have been misinformed, there being good reason to believe that this fish never ejects the liquor in question.* He adds, moreover, that this fish dies speedily, if put into fresh water, but that it will otherwise live upon its own saliva, 50 days after being taken.

In the next chapter, Pliny tells us, that the purpuræ were also called *pelagiæ*, (probably

* This is, at least, true of buccinum, whose colouring matter I found unaltered some days after the fish, or limax had died slowly, by being kept seven or eight weeks without water, and it was not until putrefaction had made a *sensible* progress, that the colouring matter became incapable of producing its proper effect.

from their inhabiting the ocean) and that there were several varieties of them, named differently from the places were they were found, and the food on which they subsisted; and he afterwards describes the manner in which they were caught. In his 38th chapter, he states, that when the purpuræ were caught, the white vein or receptacle, before described, was taken out and laid in salt for three days, after which a sufficient quantity of the matter so extracted and salted, was boiled slowly in leaden vessels, over a gentle fire, the workmen from time to time skimming off the fleshy impurities : this process lasted ten days, after which the liquor was tried by dipping wool into it, and if the colour produced by it was defective, the boiling was renewed. Pliny afterwards erroneously represents the liquor of the buccinum as only yielding a fugitive colour ; and says it was commonly mixed with more than half as much of the liquor of the pelagium, which of itself gave a very dark purple ; and that being so mixed these liquors improved each other, the latter giving permanency to the former, and being in return brightened and enlivened by it ; and thus producing a most beautiful amethyst colour. (" Amethysti color eximius ille.") He adds, that the Tyrians produced their purple, by first dying the wool with the unprepared or

greenish liquor of the pelagium, and afterwards in the liquor of the buccinum, and that this colour was deemed most perfect, when it resembled the colour of coagulated blood, &c. "Laus ei summa color sanguinis concreti, *nigricans aspectu*, idemque *suspectu refulgens*: unde & homerus purpureus dicitur sanguis."

In his forty-first chapter, Pliny farther tells us, that it not being thought sufficient to transfer the colour of the amethyst to wool, it had become the practice to dye the latter again, with the Tyrian purple, that it might obtain a compound name (Tyriamethystus,) corresponding with this double luxury: and that being saturated with colour of the conchylium, it was deemed fitter to receive the Tyrian dye. He adds, that not content with thus combining colours obtained from the ocean, recourse was also had to those produced on the land; and that wool, or cloth, dyed crimson, from the coccus (kermes,) was afterwards made to imbibe the Tyrian purple, in order that it might assume the colour which was named *hysginus*, after a flower so called: this colour partook greatly of the crimson tint. But besides the coccus (kermes,) other colouring matters were employed, sometimes to œconomize, and at others to vary the effects of the liquors of the purpura and buccinum; and more especially that of the lichen roccella, or archil, which Pliny mentions

under the name of *fucus marinus*, and which, even at this time, is greatly employed in dying, though its beautiful purple colour fades rapidly. Indeed, this lichen, or moss, was in such general use as a dye, at and before the time when Pliny wrote, that its name *fucus* came at length to signify generally, colours given by dying; of this, among numerous other instances, may be quoted the following line, by Catullus (de Nuptiis Pelei and Tetidos,) viz.

"Tincta tegit roseo conchylis purpura fuco."

of this fucus, that from Crete was the most esteemed.

Pliny tells us also, Lib. xxii. cap. 17, that the alkanet root, (anchusa tinctoria) was likewise employed as a ground for the purple dye.

By these and other means, the purple colour was made to assume a variety of shades, some inclining more to the blue, and others more to the crimson. The principal of these varieties were noticed by Pliny, in the eighth chapter of his twenty-first book, when, after mentioning the luxurious art by which men had surpassed the savour of *natural flowers*, by artificial odours, he adds, that they had also learned by dying, to emulate the finest colours of these flowers; and that of these beautiful dyes there were three divisions; one in which the coccus (kermes,) was employed, and which equalled the brightest colour of the rose, (" qui

in rosis micat;") and here he observes, that nothing could be more grateful to the sight, than the Tyrian and Laconican purples, especially when *twice dyed* (dibaphasque."*) In the second division he mentions the *amethyst*, inclining to the violet; and also the purple called janthinus.† His third division includes the colour strictly called conchylium, of *various tints*;‡ one resembling the heliotrope or turnsole, of which says he, there are several shades; another approaching the mallow, with a mixture of purple, and a third, resembling the later violet, (" viola

* Horace alludes to this twice dyed purple, (pupura di capha) in the following lines.

" Te *bis* afro murice tinctæ vestiunt lanæ"—and

" Muricibus tyriis *iteratæ* vellera lanæ."

† The amethyst purple was lighter, and partook more of the blue tint than the dark Tyrian dibapha: that variety of it called janthinus was so named from ja, a species of violet.

‡ Lucretius de rer. nat. l. vi. says of this colour:

" Purpureusque color conchyli jungitur una,
Corpore cum lana."

It was lighter and had less body than the Tyrian purple, being dyed with half the quantity of the liquor of the purpura; it also inclined more to the blue, whence it frequently acquired the names of hyacinthus, and cæruleus; and, from its having less body, those of color dilutus, and ablutus; which last word by abbreviation is supposed to have produced that of *blutus*; whence the French *bleu*, the English, *blue*, and the German *blau*. Braun says this colour is called *thechelet* in the Hebrew Bible, and the shell fish producing *it* chilzon. Braun de vests. Sacerd. Hebræor. i. 12.

serotina," probably, the purple stock gilly-flower :) this he mentions, as being the richest colour that could be obtained from the purple shell fish : and thus, says he, nature and art striving against each other, maintain an equal conflict. " Paria nunc componuntur, et natura atque luxuria depugnant."

Various (and probably fabulous) accounts of the first discovery of this purple, have been related by different writers. One of these ascribes it to a dog, who, when following the nymph Tyros, and a certain Hercules her lover, along the sea shore, caught one of the purpuræ lying on the sand, and breaking the shell with his teeth, his mouth became coloured with the purple juice, which the nymph observing, expressed a strong desire to obtain a dress dyed of this colour. And the lover anxious to satisfy her desire, discovered by a proper examination, how this beautiful purple might be obtained, and communicated by dying.* And the nymph, by whom the purple so discovered was first worn, being named Tyros, the colour is supposed to have thence obtained the appellation of Tyrian purple. Others have related, that this discovery was made by the Phœnician Hercules,† and

* See Cassiodorus, lib. i. and Julius Pollux, lib. i. 4. from the latter, Polydore Virgil has taken the story.

† Sir Christopher Hawkins, in his " Observations on the tin trade in Cornwall," (lately published) mentions this Her-

afterwards communicated it to the king of Phœnicia, who thereupon, immediately began to wear purple. (See Goguet, l. ii. ch. 2.) That this colour first became known at the city of Tyre, and thence obtained its name, is rendered probable by the fact, of its having also borne the

cules, as one said to have been the greatest Phœnician navigator, "and the first who brought tin from the Cassiterides, or British isles:" and, adverting to the story of his having also "invented the *shell purple*, by accidentally remarking that a dog's mouth was stained therewith," he observes, that "as both these discoveries are attributed to the same person, we may thence infer, that the tin of Britain was *an essential* ingredient in fixing the fine purple dyes of the ancients; or, (adds Sir Christopher,) as Mr. Polwhele elegantly expresses it, "very possibly the purple dye of the Tyrians, gained its high reputation among the ancients, from the use of our tin, in the composition of the dye stuff, as the tin trade was solely in their own management." On this subject, however, Sir Christopher, perhaps, from a partiality in him, both natural and excusable towards Cornwall, has departed from his usual logical accuracy, and hazarded an inference which his premises do not warrant; for though it were true, that tin was first carried to Tyre, and the shell purple first discovered there, by *the same person*; we should have no right to conclude that the former was necessarily employed to produce the latter; and there is not only no evidence that this ever *was*, but on the contrary, many facts prove that it never could *have been* the case; indeed, my own experiments will show, that the colourable matter of the buccinum attains its beautiful purple, and fixes itself permanently, without any *other aid* than that of solar light, and also that solutions of tin are completely useless for either of these purposes: nor is there the smallest reason to suspect that they ever were employed for dying, until the seventeenth century.

appellation of *Sarranus*, from *Sarra*, the name by which that city had been previously distinguished; and, hence the following line of Virgil, (2 Georg. 506.)

"Ut gemma bibat, et *Sarrano* dormiat *Ostro*."

Respecting the time when this discovery was first made, the more ancient writers do not agree, some stating it to have been about 1500 years previous to the Christian æra, and others almost a century later, whilst Minos reigned in Crete.

Pliny appears to think, that purple had been worn at Rome, soon after the building of that city, but that even Romulus never wore it, except in his *trabea*, or *regal mantle*: and he

In another paragraph, which Sir Christopher has subsequently quoted, from Mr. Polwhele, the latter supposes, that the Phœnicians must have known the use of tin, "as one of the non-colouring retentive ingredients;" because, "it is not likely that *the simple blood of the shell fish, however beautiful at first, could have proved a lasting dye*;" and, therefore, he imagines, that "some retentive ingredient," (like "tin dissolved in aqua fortis,") must have been necessary to secure its *brightness*, and preserve its beauty."—The "*brightness* and *beauty* of the "*simple blood of a shell fish!!*"—Of the "*purpura*," and the buccinum!!! As well might Mr. Polewhele expatiate on the brightness and beauty of the simple blood of the *oyster* and the *snail*; and suppose that by the help of tin, they would produce the Tyrian purple. How an idea so extravagant, and so indicative of gross inattention to the common productions of nature, could have occurred to this gentleman I know not, unless he derived it from the following lines of Martial, viz.

"*Sanguine* de nostro tinctas, Ingrate, lacernas
Induis; et non est hoc satis; esca sumus."

states, as a certain fact, that Tullus Hostilius was the first king of Rome, who assumed the *pretexta* or long robe, with *broad* purple stripes, after having subdued the Tuscans. He adds, " Nepos Cornelius, who died in the reign of Augustus Cæsar, when I was a young man, assured me that the light violet purple, had been formerly in great request, and that a pound of it, was commonly sold for 100 denaria, (nearly £4 sterling :) that soon after the *tarentine* or reddish purple came into fashion; and that this was followed by the Tyrian dibapha, which could not be bought for less than 1000 denaria, (almost £40 sterling) the pound; which was its price when P. Lentulus Spinter was Ædile, Cicero being then Consul. But after this, the double-dyed purple became less rare, &c." See lib. ix. c. 39.

As soon as mankind were acquainted with the purple as a dye, they seem to have considered it, not only as being of all others the most estimable in itself, but also the most acceptable to the Gods. It was, therefore, naturally appropriated to the services of religion, and of its ministers, as well as to distinguish the highest civil and military dignities. Pliny has noticed the use made of it by Romulus, and succeeding Kings of Rome, as well as afterwards by the consuls, and higher magistrates of the republic. Under the Roman Emperors, it

became the peculiar emblem, or symbol of majesty, and the wearing of it by any who were not of the Imperial family, was deemed a *treasonable usurpation*, punishable by death; as was mentioned by Suetonius. (Vita Neronis.) Hence the expressions of "sacer murex," and of "*adorare purpuram*," in the Roman laws. (See Bischoff Versuche, &c.)

When so much importance and *sanctity* (if I may use this expression,) had been attached to this colour, the dying of it was confined to a few particular places, and also to a few persons called *muricileguli*; and we need not therefore wonder, that after the Greek empire had been overthrown, the knowledge of the shell fish affording the purple colour, as well as the ways of employing them as a dye, should have been completely lost in the 12th century; and that afterwards, when learning began to revive, some persons should have doubted, whether either of these had ever existed; nor need we wonder, after this loss, that the high pre-eminence which had belonged to the purple, was in a considerably degree transferred to the scarlet, afforded by the kermes; which after being called *red purple*, at length obtained the name (unknown to the ancients) of *scarlet*,* as we

* This colour afterwards obtained the name of *Venetian scarlet*, to distinguish it from the *brighter* colour, now called

learn among others from Caneparius; who, in his work *de Atramentis*, p. 207, after mentioning that the ancient purple *then unknown*, had formerly distinguished Emperors, Kings, &c. adds, "Nostra autem ætate (the beginning of the 17th century) hujuscemodi vestes vocantur *scarlati*, quibus *Venetiis* illustrissimi, Senatores procedere conspiciuntur."—Again, in the next page he says, "Quamobrem ubique, et Venetiis præsertim maxime existimatur purpura, vulgari dictione, dicta *escarlatum*, pro illustrissimis patriciis insigniendis." He mentions also that the violet purple was then commonly called "*el Pavonazzo*," by the Italians. It was probably then dyed from archil only.

It happened, however, more than sixty years after the work of Canniparius had been printed at Venice, that Mr. William Cole, of Bristol, being at Minehead (viz. in 1683,) he was there told, of a person living at a sea-port in Ireland, "who made considerable gain by marking, with a delicate durable crimson colour, the fine linen of ladies and gentlemen, sent to him for that purpose;" and that this colour was "made by some liquid substance, taken out of a shell-fish." Mr. Cole being a lover of natural history, and hav-

scarlet and which had never been seen until Cochineal, and the effect of solutions of tin upon its colouring matter, were discovered, about the year 1630.

ing his curiosity thus excited, went in quest of these shell-fish; and after trying various kinds without success, he at length found considerable quantities of a species of buccinum on the sea-coasts of Somersetshire, and the opposite coasts of South Wales; and after many ineffectual endeavours, he discovered the colouring matter placed in a "white vein, lying transversely in a little furrow, or cleft, next to the head of the fish;" which, says he, "must be digged out with the stiff point of a horse-hair pencil, made short and tapering, by reason of the viscous clamminess of the white liquor in the vein, that so by its stiffness it may drive in the matter into the fine linen, or white silk," intended to be marked. Letters or marks made in this way, with the white liquor in question, "will presently," adds he, "appear of a pleasant green colour, and if placed in the sun, will change into the following colours, *i. e.* if in the winter, about noon, if in the summer, an hour or two after sun-rise, and so much before setting (for in the heat of the day in summer the colours will come on so fast, that the succession of each colour will scarce be distinguishable;) next to the first light green, will appear a deep green;" "and in a few minutes this will change into a full sea green; after which, in a few minutes more, it will alter into a watchet blue; from that, in a little time more, it will be of a purplish red; after

which, lying an hour or two (supposing the sun still shining,) it will be of a very deep purple red; beyond which the sun can do no more." He remarks, however, "that these changes are made faster or slower, according to the degree of the sun's heat;" "but then," adds he, "the last and most beautiful colour, after washing in scalding water and soap, will (the matter being again put out into the sun or wind to dry) be much a differing colour from all those mentioned, *i. e.* a fair bright crimson, or near to the Prince's colour; which afterwards, notwithstanding there is no styptic to bind the colour, will continue the same, if well ordered, as I have found in handkerchiefs that have been washed more than forty times; only it will be somewhat allayed from what it was, after the first washing." Mr. Cole found, that, if linens marked with the white liquor in question were taken out of the sun, when the colours had only reached any one of the before-mentioned shades, and shut up between the leaves of a book, the colour or colours made no farther progress whilst so shut up, but remained always of the same shade. He also found, that whilst linen marked with the white liquor was drying by exposure to the sun, *for the first time*, it would always "yield a very strong fœtid smell (which divers who smelt it could not endure,) as if garlick and assafœtida were mixed together;" and this hap-

pens in cases where linen, after being marked, had been shut up in a book for twelve months, before it was exposed to the sun's rays. He also found, that the colour in linen which had been dried, and washed immediately after being marked, was better than when it had lain fourteen months between the leaves of a book, unwashed.

Mr. Cole sent some of the first linen marked by him in this way, to Dr. Plot, then one of the Secretaries of the Royal Society, in November, 1684; and it was soon after shewn to King Charles the Second, who admired it greatly, and desired that some of the shell-fish might be collected and brought to town, that he might see the liquor applied, and the successive changes of colour which it underwent; but before this could be done, the king died; and though Mr. Cole's letter (from which the preceding extracts were made) was in the following year published, in the fifteenth volume of the Philosophical Transactions, and excited the attention of philosophers in most of the countries of Europe, it does not appear that any attempt was made to revive the practice, along with the knowledge, of dying the ancient purple.

After an interval of twenty-four years, M. Jussieu found a small species of buccinum, in form resembling the garden snail, on that part of the French coasts which is washed by the Atlantic ocean, and presented some of them, in

the year 1709, to the Royal Academy of Sciences at Paris; and in the following year, the celebrated M. Reaumur found great quantities of the buccinum on the coast of Poitou; and he moreover observed, that the stones, and little sandy ridges round which these shell-fish had collected, were covered with a kind of oval "graines," some of which were white, and others of a yellowish colour; and having collected and squeezed some of these upon the sleeve of his shirt, so as to wet it with the fluid or liquor which they contained, he was agreeably surprized, in about half an hour, upon finding it stained of a fine purple colour, which he was unable to discharge by washing. This was done upon the sea-shore. He next collected a quantity of these grains, and carrying them to his apartment, bruised and squeezed different parcels of them upon bits of linen; but to his great surprize, after waiting two or three hours, no colour appeared upon the spots wetted with their liquor. Unable to conceive the reason of this disappointment, and having almost determined to return again to the sea-shore, and repeat his experiment in the same place as before, he chanced to perceive some purple spots, occasioned by drops of the liquor which had accidentally fallen upon a part of the plaster of Paris with which the sides of the window were covered, and which, having been more strongly acted upon by the light,

than the bits of linen wetted with the same liquor in the interior part of the room, had become purple, though the day was then cloudy. Without, however, perceiving this to have been the cause of his disappointment, he broke off a bit of the same plaster, and carrying it to the back part of the room, where the bits of linen in question were laying, he wetted it with the same liquor, without its becoming coloured. He then thought of carrying the colourless bits of linen to the window, which was open, and there he soon perceived them to become purple. It was then fashionable to explain all effects upon mechanical principles, as it had been at the time when he also endeavoured to account for the shock of the torpedo, as resulting *mechanically* from a very quick stroke given by the contraction of particular muscles in that fish. M. Reaumur, therefore, soon persuaded himself, and others, that the bits of linen which had remained colourless whilst at the back part of his room, were rendered purple at the window by the different manner in which the air acted upon the colouring liquor in the latter; and that this difference consisted solely in the air's having greater motion at the window, than at a distance from it; and almost all his subsequent experiments, seem to have been calculated to confirm this erroneous hypothesis.

He placed bits of linen, just wetted with the

colouring liquor, in the open air, and laying a stone upon each, he found the covered part remain colourless, whilst the rest were made purple; which he ascribed to the mechanical impression of wind, not considering that the stones kept off the light, as well as the air.—Having read an account of Mr. Cole's observations, in the Philosophical Transactions, M. Reaumur exposed a bit of linen, wetted with the colouring liquor, to the rays of the sun, collected by a small burning glass, and saw it become purple in an instant; and consequently, without being able to distinguish any of the changes of colour through which it had so rapidly passed. Putting another bit of linen, wetted with the same liquor, so near to the fire that it would have burned had it been dry, he likewise saw it become purple immediately; but with equal degrees of heat, the effects produced by the sun's rays were beyond comparison the greatest.

M. Reaumur conceived the grains in question to be the eggs or spawn of some fish, but whether of the buccinum, or any other species, he was uncertain; and under this uncertainty he proposed calling them "Oeufs de pourpre," eggs of purple. The colour which they produced, was at least equal, if not superior in beauty, as well as durability, to that of the buccinum: though the colouring liquor of the lat-

ter was much thicker than that of the purple eggs, and not liable to pass through the different changes of colours so quickly as that of the eggs, excepting when diluted. Having put some of this diluted liquor into two glasses, and placed one of them in contact with the sun's rays, and the other near the fire, the former became purple without any sensible addition of heat, whilst that which was at the fire had only began to acquire the first shade of colour, though it was sensibly hot: and indeed he always found the colours produced by the sun to be more beautiful than any others; a circumstance which he endeavours to explain, by supposing its rays to act mechanically, in changing the figures or arrangements of the particles of the liquor, in the same way as he supposed the wind to change them, but with more efficacy.

M. Reaumur perceived the same disagreeable smell of garlick from the liquor, which Mr. Cole had before mentioned; and he found it the more insupportable, as the heat of the sun or fire was the strongest. The colour of the liquor was not produced, or affected either by vegetable alkali (carbonate of pot-ash), or sulphuric acid; but a very little corrosive sublimate of mercury, put into the diluted liquor of the buccinum, instantly rendered it blue, and the colour was soon precipitated with the mercury, to the bottom of the vessel, leaving the liquor colourless; an effect

which, as usual, he endeavoured to explain mechanically, by supposing the sublimate to consist of little globules, stuck round with sharp points, which enabled it to change the arrangement of the particles of the liquor more expeditiously, even than he had supposed it done by the wind. He found that the liquor of the buccinum tasted as hot as the hottest pepper, whilst that of the purple eggs was saltish; but even this was so viscid, that it did not run, when topically applied to linen, &c.; and as the eggs were, according to M. Reaumur's account,* so plentiful, that one man might collect half a bushel of them in a few hours, there certainly is reason to think, that they would be highly useful, at least in calico printing, where their liquor might be applied, with the greatest facility, both for penciling and printing, as a substantive topical colour, and where a small quantity would go far, especially upon fine muslins. But at that time the art of calico printing had not been practised in France, and therefore nobody thought of applying Mr. Reaumur's discoveries in that way.

About the beginning of the year 1736, M. Duhamel found the *purpura*, (the buccinum only having been discovered by Cole and Reaumur,) in great abundance upon the coast of Provence;

* In the Mem. de l'Acad. Royale des Sciences, &c. an. 1711.

and observed it to agree very well with the description thereof, given by Rondelet. He found the viscid colouring liquor of the fish to be white, except in a few instances, where it was green, which he suspected to be some morbid effect. The white liquor being exposed to the sun's rays, assumed the following colours; 1. a pale yellowish green; 2. an emerald green; 3. a dark blueish green; 4. a blue, with a beginning redness; and 5. a purple; and these changes all happened in less than five minutes. Linen wetted with the white liquor, and left all night in a dark room, had only become green in the morning; and this was also the case of linen wetted in like manner, and exposed all night in the open air, but shaded from the moon's light. A piece of linen, wetted in the same manner, being partly exposed to the sun's rays, and partly hid by a crown-piece of silver, the former part became purple, whilst the latter was only green. Other linen so wetted, being heated in a Duch oven before the fire, or upon a hot iron, became of a dark green, but not purple. The fumes of burning sulphur only produced a dark green; and this was moreover the case with the different coloured rays of the sun, applied separately by a prism. Wishing to see whether evaporation tended to colour the white liquor, Mr. Duhamel put some of it into a phial well stopped; and, upon exposing it to the sun,

found the liquor become of a reddish purple almost immediately. A piece of linen wetted, and stuck upon the back of a plate of polished glass, three lines in thickness, and exposed to the sun's rays, became purple even before it had dried. Three pieces of linen so wetted, being covered, one with white, a second with black, and the third with oiled paper, the last soon became of a good purple colour, but the others only became green. Linens wetted in like manner, and exposed to the light of the moon, or of burning wood or candles, became green, but not purple. Exposure to the sun's rays always produced the purple, and most expeditiously, when its light and heat were strongest, the sun-shine of the month of March having proved much more efficacious than that of January or February. The purple was instantly produced by the sun's rays, collected under a burning glass. The liquor which M. Duhamel suspected to be morbidly green, became purple sooner than the white liquor; a circumstance which does not indicate its greenness to have been the effect of disease. In linens where the colour had stopped at the green, without reaching the purple hue, it was soon carried off by boiling with soap, fossil alkali, alum, &c. which the colours that had already become purple, withstood for a long time, and were not hurt by the fumes of burning sulphur. See Memoirs of the Royal Academy of Sciences, &c. 1736.

Until Mr. Cole had discovered the buccinum, no adequate conceptions could have been formed of the changes, through which its liquor, and that of the purpura, became purple. Aristotle and Pliny had, indeed, both given intimations of its being primitively white; and Pliny had slightly mentioned one of the intermediate colours, the green.* That the other changes were not more distinctly noticed, must be ascribed to the little attention then bestowed upon subjects of natural philosophy, and perhaps to a want of sufficient communication with the purpurarii piscatories, by whom the liquor was collected and salted. And there can be no doubt of the identity of the shell-fish employed by the ancients, and those discovered by Cole, Reaumur, and Duhamel, or of the similitude of their changes, and of the means by which their several liquors became purple. In a collection of Anecdota Græca, lately published by M. d'Anse de Villoison, from MSS. preserved in the King's library at Paris, and that of St. Mark, at Venice, there is a description of the manner of catching the shell-fish, employed for the purple dye, written by an eye-witness, Eudocia Macrembolitissa, daughter of the emperor Constantine the eighth, who lived in the eleventh century, while

* "Color austerus in Glauco, et irascenti similis mari." Lib. ix. cap. 36.

the knowledge and practice of dying that colour for the use, and at the expence, of the Greek emperors still subsisted; and from which it manifestly appears, that in those times, as well as in ours, the purple did not acquire its due lustre and perfection until it had been exposed to the sun's rays.

Those who are duly acquainted with the more recent chemical discoveries, can only hesitate between two ways of accounting for the changes through which the liquors of the purpura and buccinum become purple; I mean, whether it be by gaining oxygene from the atmosphere, like indigo, when it acquires its blue colour; or by the separation of a redundant portion of oxygene, naturally combined for some unknown purpose, in the liquor of these shell-fish; and in that particular state which will not admit of its being separated without the application and assistance of light; as is also the case of horned silver, rendered purple by the sun's rays; of vegetables, rendered green by the same cause, after they had become white by growing in darkness; of peaches, purple grapes, and other fruit, which never acquire their proper colours by any degrees of heat, but always remain white or green, if shaded and secluded from the contact of the sun's rays. A very few experiments, which I hope to have an opportunity of making hereafter, would ascertain this point beyond the

possibility of doubt; though in fact there is, I think, at present, very little room to doubt but that the purple, under consideration, is produced in the last of the two ways just mentioned.*

Such were the conclusions which I had formed, and published in 1794; and it will soon be found that they have since been completely verified, by the most decisive experiments.

In the month of September, 1803, Mr. Samuel Richardson, of Cowbridge, in Glamorganshire, at the request of my truly respectable friend Dr. Cheston, of Gloucester, obligingly procured and forwarded to me a large parcel of shell-fish, (apparently of that species with which the experiments of Mr. Cole had been formerly made,) belonging to the genus of Buccinum (commonly called whelks) and agreeing in their specific character, with the *Buccinum lapillus* of Linnæus.

I had no difficulty in finding and extracting the colouring matter of these Testacea, which in appearance and consistence very much resembled well-formed pus, and was collected to the amount of two or three drops in a little whitish *cyst*, placed transversely under, but in immediate contact with the shell, and

* M. Berthollet on the contrary appears to believe that the effect in question, is produced by a farther combination of oxygene. See Elements, &c. tom. i. p. 144, last Edition.

near the head of its inhabitant the limax. The white slightly yellowish colour of this cyst, and of the matter contained therein, rendered it perceptible by close inspection through the semitransparent substance of the shell, though the latter was not furrowed or channelled, where the cyst came in contact with it, as I had supposed from Mr. Cole's description.

This pus-like matter, either diluted with an equal portion of water, or undiluted, being applied to bits of white linen or calico, became purple after going regularly through the intermediate colours mentioned by Mr. Cole, and in the same order. And these changes were completed in a very few minutes, when the sky was serene, and the bits of linen or calico were, *in summer*, fully exposed to the sun's beams; and more especially with the diluted matter; for the undiluted, being often *confined with too much body*, in a small space, was not so soon thoroughly penetrated and changed by the solar rays.

I mixed different parcels of this matter with each of the several alkalies, both in their mild and caustic states, and having applied them to linen and calico, I found that instead of *retarding* the progress of these changes, and the ultimate effect of a *purple* colour, they rather produced an acceleration thereof: and this was the case in a more remarkable degree, when the matter in question was mixed with alcohol, or the

volatile essential oils of cajeput, turpentine, lavender, &c. or with *muriatic acid :* on the contrary, these changes appeared to be considerably retarded, by the admixture of nitric acid, though it did not hinder them from ultimately taking place. Sulphuric acid had a similar effect, but in a lesser degree, as had the citric, and acetous acids, and that of tartar. The same matter applied to muslin, and put into a glass filled with hydrogene gas, and closely stopped, being exposed to the direct rays of the sun, went through all the before-mentioned changes in one third less time than usual ; whilst similar matter, confined in the same manner with oxygene gas, and exposed at the same time, underwent these changes more slowly : and nitrogen gas employed in the same way, and at the same time, had no apparent influence upon them. These, and other experiments, rendered it at least *highly probable* that *a separation*, and not *an addition*, of oxygene accompanied and contributed to the attainment of the purple colour in question. But before I had made all the experiments which seemed necessary to ascertain the fact, my attention was unavoidably diverted to other objects ; and fearing that my whelks might die, and become unfit for other experiments before I could find leisure to make those which I had projected, I broke the shells of at least one hundred of them, and after extracting their

colouring matter, and applying it undiluted to bits of calico and muslin, I placed these bits separately, and as expeditiously as possible, each between two leaves of a large blank folio book, and afterwards kept it *closely shut*, to exclude the light: believing, though the matter in question had not been allowed to become dry before it was shut up in this way, that so much of its moisture would be absorbed by the paper, as to obviate any putrefactive process, and that if this could be obviated, the matter in question would continue fit for my experiments, so long as it should be kept secluded from light. And in these respects my belief appears to have been well founded, since even now (August, 1812,) when almost nine years have elapsed, I find that the bits of muslin so shut up, (of which a score are still remaining) exhibit only the yellowish spots given by this matter as when first applied to them, and that they are as capable as ever, of passing through the usual changes of colour, and finally becoming purple, if assisted by the sun's rays. They do this indeed more slowly, when exposed without being *first moistened;* but after being dipped in water, the changes succeed as regularly, and quickly, as they have usually done with matter just taken from its natural receptacle, and the experiments which I am now about to relate, were all made with the matter which had been so applied, either

to muslin or calico, and secluded from light, more than seven years.

1st. A bit of calico, so impregnated and secluded from light, was put into a very small white glass phial, and the latter being filled with strong nitric acid, which had been diluted by about five times as much water, it was stopped and exposed to the rays of the summer's sun: and in about *twice* the usual time, as nearly as I could judge, the yellow spots became first greenish; then of an apple green, and afterwards of a deep grass green colour: but here the progress appeared to stop so long, that I began to think it would proceed no farther: at length, however, a blue tinge became evident, then a deep blue, and finally a purple; so that the oxygene of the nitric acid, though it manifestly retarded the usual changes, did not hinder their ultimate accomplishment. This experiment was repeated, with a substitution, first of diluted sulphuric, and then of citric acids, instead of the nitric; and with a similar *obstruction* to the usual changes, though it was of less duration; this also happened with the acid of tartar. A similar experiment being made with *undiluted muriatic* acid, the several changes terminating in a *fine purple*, were all completed, and, as I thought, in little more than half the usual time.

This experiment was repeated with bits of impregnated muslin, by substituting caustic

solutions of potash, soda, and ammonia separately, for the acids before mentioned, and in all of them, the purple colour was produced, after the usual changes, in full perfection, and, as I thought, with greater celerity than they had formerly been with the matter just extracted from the buccinum; and this also happened with muslin immersed in olive-oil.

A similar bit of muslin put into a phial completely filled with a solution of tin, in muriatic acid, which had been recently made, and was at the minimum of oxidation (if not destitute of oxygene) upon being exposed to the sun's rays, became purple with great celerity, after passing through the usual succession of colours: and this was the case with another bit put into a phial and filled with the oxymuriatic acid (chlorine of Davy) as concentrated as any which I could procure. This last result appeared to me the more extraordinary, because I had previously seen this acid exert its destructive influence, upon the purple of the buccinum produced in other ways, almost as quickly and efficaciously, as it is known to do upon colouring matters generally: and I therefore prolonged this experiment, by removing the phial, when the purple was completely formed, to a situation where the *direct* rays of the sun could not reach it; and there I found, after a few hours, that the very same acid which appeared to have accelerated the production of

this purple, had afterwards annihilated the colour so produced, leaving the muslin perfectly white !

That I may not unnecessarily prolong this account of my experiments, I will omit several of lesser importance, and proceed to a recital of *two*, which I think conclusive, in regard to the *problematical* part of this inquiry, viz.

First,—Into a flint glass phial, more than half-filled with quicksilver, (strained through leather,) I conveyed a triangular bit of fine muslin, impregnated, dried, &c. as before mentioned; and having *attached* one corner thereof, by compressing it between the glass stopper, and the opposite inner surface of the mouth of the phial, I inverted the latter, so that the quicksilver sunk down to its neck, pushing the muslin (which by this attachment was hindered from ascending, and which had been previously spread,) closely upon one side of the inner surface of the phial, the other surface being in immediate contact with the quicksilver, which rose an inch above the muslin; so that the latter, was completely secured from the access of atmospheric air; that which the phial contained, being forced by the superior weight of the mercury, into the space above it. Thus circumstanced, the phial (in the month of August,) was exposed to the sun's rays, that side of it, upon the inner surface of which

the muslin was applied, being turned *towards them:* and in this situation I observed the muslin, or rather the colouring matter of the buccinum, to pass through all the shades of green and blue, and become a full reddish purple with as much celerity, as similar matter in a dried state, had commonly done, when exposed to the sun's beams, with the free access of atmospheric air.

Though it appeared difficult to devise any experiment more decisive than this, I made a second, by filling with quicksilver, a small cylindrical glass tube, 34 inches long, and closed at one end; and having stopped the orifice with my finger, I inverted the glass upon a china cup, containing more quicksilver, and then, withdrawing my finger, the mercury sunk, and left a vacuum above it, of about four inches in height: I then placed a bit of fine muslin impregnated, dried, &c. as before mentioned, under and immediately *before* the orifice of the tube, through which it ascended with great rapidity into the vacant space, and being then exposed to the sun's rays, the usual changes, terminating in a purple colour, *all took place*, as in the preceding experiment, and with equal celerity.

In the first of these latter experiments, there was no vacuum, but the muslin with its colouring matter, was in *close*, and *immediate* contact with the inner surface glass, and with the

quicksilver in every other part; so that nothing else could possibly reach the colouring matter, excepting the light passing through the glass. In the second experiment, the muslin was placed *in vacuo,* but the colouring matter, was equally protected by the glass and quicksilver from the access of every thing but light. In both experiments, the bits of muslin employed, were perfectly dry, and the quicksilver, when brought into contact with them, occasioned no change or impression whatever, upon the colouring matter, not an atom of it adhering thereto, or to any part of the muslin. The changes of coloûr therefore could only have been occasioned by the sun's rays, and it is now well known, that their most common and general effect upon colouring matters is, that of separating oxygene: —their other effect, of promoting a combination of it, could not possibly have been produced in these experiments, where no oxygene existed. Wishing, however, to obtain as much additional evidence as possible, concerning the sort of action exercised by the sun's rays, in producing the changes before mentioned, I took a piece of muslin impregnated, &c. as in the former experiments, and having wetted it with water, which had just boiled and was partly cooled, I spread the muslin on white paper, in a place accessible to the sun's rays, and separating the latter by a triangular prism, I brought the solar spectrum to bear completely upon the colouring matter of

the buccinum, and was soon convinced that the usual changes of colour proceeded faster and more distinctly under the *deoxygenating rays*, at the *violet* extremity, than they did at the other extremity under the red rays; the muslin becoming *purple* at the former, whilst at the latter it had become only *blue*.

There is, moreover, another proof of the separation of oxygene, when the purple under consideration is produced, and it is connected with the strong disagreeable odour, nearly resembling that of *garlic*, which was so distinctly perceived by Cole, and Reaumur, and which has constantly assailed my nostrils, whenever the colouring matter of the buccinum began to turn green, and has continued to do so, without diminution, until some time after the purple colour was fully produced. This odour to my senses, unequivocally indicates the presence of phosphorus, which is contained in all animal substances; and, when subjected to the action of the sun's rays, readily becomes volatile in part, by combining with a portion of oxygene; and this volatile part or compound (which, as Davy observes, p. 287, "should, according to the principles of the French nomenclature, be called *phosphorous acid*") emits an offensive *alliaceous smell*, very much like that of the colouring matter of the buccinum, when it becomes purple. The last, or that part of it which gives the smell of garlic, readily mixes with water, and strong-

ly impregnates it with this odour, as I have found by many experiments; and in this respect it also agrees exactly with the volatile compound which gives the alliaceous odour from phosphorous.

I repeated Reaumur's experiment with corrosive sublimate of mercury, and found that the purple which resulted, partook more of the blue tint than usual, and this appeared to be the case when the colouring matter of the buccinum was mixed with sulphate of iron.

Pliny, as my readers will have seen, represents the purple colour obtained from the buccinum, as not being permanent, without a mixture of that from the purpura; but on this point he was certainly misinformed, it being of itself the most durable of all animal colours. I found that it was not sensibly affected, even upon fine muslin, by being *wetted* with undiluted oxymuriatic acid, though when immersed in a phial filled with this liquor, it soon disappeared, as I believe would happen to almost every other animal or vegetable colour. I found also that undiluted oil of vitriol dropped upon a bit of calico, which had been made purple by the matter of the buccinum, *did not destroy the colour*, though it produced a tinge inclining more to the *blue*. Highly concentrated and smoking nitrous acid, applied to a similar bit of calico, changed the purple to a yellow colour, which became very

lively and beautiful, upon being rinced in a solution of potash. Thinking it not unlikely that this change might have resulted from a combination of oxygene, with the colouring matter, rather than from an *irreparable decomposition of it*, I exposed the yellow in question to the direct action of the sun's rays, to see whether their deoxygenating power would reproduce the purple, but no such effect ensued; the yellow remaining, and seeming to be permanent. Strong muriatic acid applied to a similar bit of calico, appeared to have no effect upon the purple colour; and single aquafortis changed it less than the much weaker oxymuriatic acid.—But I will proceed no farther with my observations, believing that I have now sufficiently explored and elucidated this hitherto abstruse subject. Some of my readers may indeed think that I have been too minute in my statements concerning it. But to me, the colouring matter under consideration, has appeared to deserve my utmost attention, because, (independently of the veneration with which it was contemplated by the ancients) its properties are more extraordinary, more interesting, and more instructive, than those of any other. It is strictly, and preeminently, intitled to the distinction of a *substantive* colour, as it may be permanently fixed, even upon linen and cotton, by the most simple application, and without any preparation or admixture whatever;

and it is admirable, for the singular constancy with which it proceeds, through the series of intermediate colours, (according to their prismatic arrangement) until it has permanently *fixed itself*, and attained that purple tint, which the author of nature, for some unknown purpose, has fitted it to display; and all this, *in spite*, if I may so express myself, of many powerful chemical agents, whose utmost influence extends only to retard, for a few hours, the ultimate accomplishment of this its destiny.

The celebrated Fontenelle, in giving (as Secretary of the Royal Academy of Sciences at Paris) his account of Reaumur's discovery, began by observing, that not only more things were found in modern, than had been lost in ancient times, but that it was even impossible for any thing to be lost unless mankind were willing that it should remain so; it being only necessary to search in the bosom of nature, where nothing is annihilated; and that to be certain of the possibility of a thing's being found, was a considerable step towards finding it. But before the buccinum and purpura were found by Cole, Reaumur, and Duhamel, America had been discovered, and new dying materials thence obtained, superior in beauty, and especially in cheapness, to those so highly valued in ancient times; though it must be confessed, that no other substance will afford a substantive purple of equal

beauty and durability, and capable of being topically applied to linen and cotton with so much simplicity and expedition; and for these reasons it seems probable that the discoveries of these Gentlemen might still be rendered beneficial in staining or printing fine muslins, for which but little colouring matter is required. And indeed, there was a species of buccinum found more than a century ago near Panama, on the coasts of Guayaquil and Guatemala, of which constant use appears to have been made in those countries, for the dying or staining of cotton, as Jussieu, the elder, Thomas Gage, and others have mentioned. Don Antonio Ulloa, in particular, says, "they are something larger than a nut, and contain a juice which, when expressed, is the true purple; for if a thread of cotton or the like be dipped into this liquor, it becomes of a most vivid colour, which repeated washings are so far from obliterating, that they rather improve it; nor does it fade by wearing." "This precious juice," continues he, "is extracted by different methods; some take the fish out of the shell, and laying it on the back of the hand, press it with a knife from head to tail, separating that part of the body into which the compression has forced the juice, and throw away the rest." This being done, "they draw threads through the liquor which is the whole process; but the purple tinge does not

appear immediately, the juice being at first of a milky colour, from which it changes to a green, and, lastly, to this celebrated purple." See the translation of his account of the voyage to South America, &c. vol. i. p. 268-9.

Snails, with the same property, exist in various other parts of the world. Catesby, in describing the Bahama islands, (vol. i. p. xliv.) mentions among the shells there, the "Buccinum brevi rostrum muricatum, ore ex purpuro nigricante dentato," adding "these shells stick to rocks a little above low water, and are consequently a short time uncovered by the sea. They yield a purple liquor, like that of the murex, which will not wash out of linen stained with it."

Josselyn also, in his "New England Rarities discovered," p. 37, says, "at Paschataway, a plantation about 50 leagues by sea, eastward of Boston, in a small cove, called Baker's Cove, they found this kind of muscle, which hath a purple vein, which being pricked with a needle, yieldeth a perfect purple or scarlet juice, dying linen so that no washing will wear it out, but keeps its lustre many years: we mark our handkerchiefs and shirts with it." Mr. John Nieuhoff moreover relates, that "*abundance* of purple snails are found in the islands over gainst Batavia." "They are boiled (adds he) and eaten by the Chinese, who have a way of polishing the shells, and pick out of the middle of the snail a certain

purple-coloured substance* which they use in colouring, and in making red ink.

In the fiftieth volume of the Philosophical Transactions, Dr. J. A. Peysonnel, F. R. S. describes what he calls the naked snail producing purple, ("Limax non cochleata, purpur ferens,") as being found in the seas of the Antilles, and "precious for the beautiful purple colour it produces in the same manner that the cuttle-fish produces its ink." "There is (continues he) a hollow in the back of the animal where the canal, filled with a reddish juice, passes out, carrying it to a fringed body like a mesentery; and it is there the purple juice is brought to perfection." "When the animal is touched, he makes himself round and throws out his purple juice as the cuttle-fish does his ink: this juice is of a beautiful deep colour; it tinges linen, and the tincture is difficult to get out."

It is however to be remarked, that the liquor of the naked snail exists naturally of a purple colour, without the application of light; a circumstance which denotes very different proper-

* Probably this description is inaccurate, for if the substance in question, exhibits a purple colour, when taken immediately from the body of the snail, it must differ in its nature and properties, from the purple of either the murex or buccinum, and nearly resemble that of the snails, mentioned in the succeeding paragraphs.

ties from those of the buccinum. In Brown's History of Jamaica, there are descriptions of two shell-fishes having a similar colouring liqu r; one is termed "the larger dark lernea, or sea snail, frequent in the American seas." Dr. Brown observes, that "on touching this creature, it emits a considerable quantity of viscid purple liquor, which thickens and colours the water about it so much, that it can scarcely be seen for some time after, by which means it is generally enabled to make its escape in times of danger." "I have gathered," adds Dr. Brown, "a small quantity of the discharges of this creature, and stained a linen handkerchief there with it; it gives a very beautiful dark purple colour, which is not apt to change with either acids or alkalies; but is easily washed out:" a circumstance in which it totally differs from the buccinum, &c. as well as in that of the liquor being naturally emitted of a purple colour. The other, of these shell-fishes, is termed cochlea ima, or the purple ocean shell; and upon being touched, "it diffuses a beautiful purple liquor," says Dr. Brown, which seems to resemble the former. The sepia, or cuttle-fish, has long been known to provide for its safety in like manner, by discharging in times of danger, a viscid bitter black fluid, which Rondeletius mistook for bile, and which, I know by experiments, to be as dissimilar as possible, to the colouring matter of the

buccinum, and utterly incapable of serving any useful purpose in dying; and I am persuaded, this must be true, also, of the liquor of Dr. Brown's shell-fishes, and that of Dr. Peysonnel's naked snail. A similar mistake seems to have been committed by M. Cuvier, one of the latest, most respectable, and best-informed writers upon comparative anatomy, who has evidently confounded the *testacea*, affording the purple of the ancients, with a considerable number of the vermes of Linnæus, (principally molluscæ) naturally destined to secrete, and when in danger to *eject*, dark-coloured fluids, that, by obscuring the water, they may be enabled to escape; a purpose totally different from that of any fluid secreted by the murex or buccinum, and affording the purple of the ancients. See Cuvier's Anatomie Comparée, tom. v. 263, 4.

Mr. Martin Lister, (see Philosophical Transactions, vol. vi.) observes, that "the common hawthorn caterpillar will strike a purple, or carnation, with lye, and stand; the heads of beetles and pismires will, with lye, strike the same carnation colour, and stand; and the amber-coloured scolopendra (adds he) will give, with lye, a most beautiful and pleasant amethystine, and stand:" but whether he means that they will stand in this way, when applied to paper only, or to the substances usually made to receive dyes, does not appear. In another

part of the same volume, Mr. Lister mentions an insect (cimex,) whose eggs, bruised upon white paper, " stain it of themselves, without any addition of salt, of a lively vermilion colour."

CHAPTER V.

Of Vegetable Substantive Colours, and principally of Indigo, and the plants affording it, or a similar Colour.

"Combien de tentatives n'aura t'on pas fait, avant que de parvenir au point d'appliquer convenablement les couleurs, sur les etoffes, et de leur donner cette adherence et ce lustre, qui fait le principal merite de l'art du teinturier, un des plus agreables, mais en meme temps un des plus difficiles qu'on connoisse!" GOGUET *de l'Origine des Lois, des Arts, et des Sciences, &c. tome premier,* 4to.

THE subject of this article, is the most interesting, important, and instructive, which can occupy the attention of a dyer, or a chemist; the admirable and singular properties of indigo being only surpassed by those of the colouring matter of the murex and buccinum, a little, while it is of much higher practical utility than the latter. From the remotest ages of which we have any correct information, mankind appear to have possessed and employed the means of dying or staining *blue* colours substantively, either upon their skins or clothing. In the more temperate climates, this was done from the plant denominated *isatis*, by Linnæus, as well as by the Greeks and Romans, and commonly known in this country by the name of woad: but in warmer situations, the colour in question was chiefly obtained from some of the indigoferæ (of Linnæus), or other vegetables of the natural

order of Papilionacææ, or that of leguminosæ. The plants so employed, all contained more or less of the *basis* of indigo, combined with but a *small* portion of oxygene, and therefore capable of being extracted, and held in solution by water, long enough at least for its application as a dye. And it is not therefore surprizing that the inhabitants of all countries, excepting India, should have thought it sufficient to pound or grind the plants naturally containing this basis ; and after a partial and premature fermentation, in some places, to dry the matter so pounded or ground ; leaving the dyer, when necessary, to macerate and give it an additional, or other sufficient fermentation, to enable the basis to absorb such farther portion of oxygene, as, when assisted by the dying process, would fix it permanently in the dyed cloth, and fully manifest its *blue* colour.

This *partial* fermentation of the bruised plant, previous to its being dried, was chiefly practised in regard to the woad or *isatis*, of which two species, differing but little from each other, are cultivated in Europe, viz. I— Tinctoria, and I— Lusitanica :* with the indigo plants this

* The preparation given by the Greeks and Romans to the isatis, is not I believe described by any of their writers, but that of the moderns is well known. The plant, after being cut, washed, and partly dried, is carried to a mill, and there ground to a paste, after which it is formed into a mass or heap, and being covered to protect it from rain, is left to undergo a partial fermentation

sort of fermentation seems not to have been thought necessary,* by a great part of mankind.

for about a fortnight—The heap is then stirred, well mixed, and formed into balls or cakes, which are exposed to the sun and wind to dry, and thereby obviate the putrifactive process, which would otherwise take place. Being afterwards collected in heaps, these balls again ferment, become hot, and emit the odour of ammonia or volatile alkali, which, as Mr. Hume tells us, in the 44th chapter of his History, gave such offense to Queen Elizabeth, that she issued an edict to prohibit the cultivation of this plant: had she prohibited the making it to ferment, except by the dyer, she would have acted more wisely. After the heat has continued for some time, these balls fall into a dry powder, and are then sold to the dyer, who now seldom employs them without a mixture of indigo, which last the woad helps to deoxygenate and render soluble. Formerly, however, this preparation, fermented by well-known means, was employed *alone,* though it was incapable of giving a deep and bright blue colour, because the tingent matter was in union with too great a proportion of the other constituent matters of the plant. The colour, however, which it did give, was very durable. But the best methods of conducting the fermentation and preparation of woad are, even at this time, so little understood, by the persons exercising that employment, that the goodness of any parcel of it can never be ascertained, otherwise than by the actual use which dyers afterwards make of it, and this commodity is therefore purchased under the greatest uncertainty respecting its true value, and it would therefore be better to dry and sell it unfermented. It has lately suited the policy of the French government, to cause the isatis to be cultivated for the purpose of obtaining indigo from it, by a process analogous to that employed

* François Cauche, after describing the indigo plant at Madagascar, says the natives "pillent les feuilles avec leur branches, etant encore tendres, et en font des pains, chacun

By what circumstance or event the people of Hindostan alone were led, several thousand years

employed in the East and West Indies, with the indigofera tinctoria, and I have seen some of the indigo so produced, but I do not think that in goodness and cheapness it can ever rival that from the indigo plants, which at the proper age will afford nearly thirty times as much indigo, as an equal weight of the isatis tinctoria.

de la pesanteur de trois livres, qu'ils font secher au soleil; s'ils veulent teindre, ils en pillent un, ou deux, ou trois, suivant qu'ils en ont besoin, et mettent la poudre dans des pots de terre, qu'ils font bouillir avec de l'eau sur le feu' puis tirent leurs pots, laissant refroidir cé qui est dedans, y trempant leur cotton et leur soye." Voyage de Francois Cauche, en l'isle de Madagascar, &c. 4to. Paris 1651. p. 151. M. Adanson gives a similar account, of the method of using the indigo plant by the natives of Senegal, except that he mentions, as perhaps Cauche ought to have done, that a lye of vegetable ashes is employed in dying with it. See his voyage, &c. Capt. George Roberts also, in the account of his four years' voyages, mentions the indigo plant as growing wild at Bonavista, one of the Cape de Verd islands; and that the natives prepare it, "only by pounding the leaves of the shrub while green, in a wooden mortar, with a wooden pestle, and so reduce it to a kind of pap, which they form into thick round cakes, or balls, and drying it, keep it until they have occasion to use it for dying their clothes."—He observes that the cakes in drying, change from a green to a blue colour, (probably by absorbing oxygene) and that the natives extract the dye by means of a lixivium," as I suppose, of wood ashes. Mr. Mungo Park, in the account of his travels in Africa, says, that to dye cloth of a lasting blue colour, according to the practice of the negro women, "the leaves of the indigo when fresh gathered, are pounded in a wooden mortar, and mixed in a large earthen jar, with a strong lye of wood ashes, (chamber-lye

ago, to discover and adopt means by which the blue colourable matter of the indigo plant, might be extracted, oxygenated, and precipitated free from almost all the other matters naturally combined with it, and afterwards brought into the dry solid form in which we now find it, no one can I believe conjecture. But, as an accurate knowledge of the process by which all this can best be effected, will greatly conduce to a right understanding of the nature and constitution of this wonderful, and most valuable production, I shall endeavour to give the best pos-

being sometimes added) and the cloth is steeped in this mixture, and allowed to remain until it has acquired a proper shade.'—"When indigo is most plentiful, they collect the leaves, and *dry them in the sun,* and when they wish to use them, they reduce a sufficient quantity to powder, and mix it with lye as before mentioned." Vol. i. p. 97.

Mr. Marsden, in his History of Sumatra, p. 78, says "the indigo shrub (Taroom) is always found in their plantations, but the natives to dye with it, leave the stalks and branches for some days in water to soak, then boil it, and with their hands, work some chunam (quicklime) among it, with the leaves of the pacoo sabba (a species of fern) for fixing the colour. They then drain it off, and use it in a liquid state."

To conclude this note, I shall only add the following extract from Mr Barrow's Travels in China, p. 560, "Near most of the plantations of cotton we observed patches of the indigo; a plant which grows freely in all the middle and southern provinces. The dye of this shrub, being *no article of commerce in China,* is seldom if ever prepared in a *dry state,* but is generally made to communicate its colouring matter *from the leaves.*"

sible account and explanation of it, availing myself of every thing which has been done by others, as well as by myself.

It has been already stated, and will hereafter be abundantly proved, that indigo principally, and *essentially*, consists of a peculiar colourable matter, which I call its *basis*, and which being combined with a certain portion of oxygene, is, while this combination subsists, thereby rendered *insoluble* by any means yet known, excepting those which exert an agency, more or less *destructive* upon the *basis itself*. This basis is colourless when destitute of oxygene, and seems to be *formed* by certain *peculiar* secretory organs, bestowed upon a few particular plants, some of which have been already noticed, and others will be mentioned hereafter: but though it manifests a strong affinity for oxygene, when separated from the different matters with which it is mixed in the plant, the basis is naturally combined with so little of it, as to be liable to decomposition and injury from various causes, which would have no such effect upon it, when sufficiently oxygenated, as it is in the state of indigo. I have observed repeatedly, by gathering the fresh leaves of the indigo plant, inclosing them in a piece of white calico, and pressing the latter strongly upon the leaves, so as to make it imbibe their juice, that a greenish tinge was

first produced on the calico, which in *drying*, approached to the blue, and ultimately assumed that colour; though it was very pale, because the proportion of colouring matter, or rather of its basis, naturally dispersed through the juice of the plant, was too small to produce any other than a feeble colour—it was however so completely fixed, that repeated washings with soap, had only the effect of rendering it brighter by removing the other matters contained in the juice of the plant, and applied to the calico with the blue colouring matter. By repeating these applications (of the juice of the leaves in question) to the *same piece* of calico several times, I found that an addition of blue colour was made by each, and as the colour so communicated was permanently fixed, I have concluded that in regard to the *degree* of its oxydation, the basis of indigo so applied, was nearly in the state, in which it commonly is, in the composition to be hereafter described, which the calico printers apply by the pencil, to give permanent blue stains, or figures. I suspect, however, that the basis of indigo, when thus applied to calico, in union with the *unfermented* juice, does not afterwards oxygenate itself so perfectly, as it does when made into indigo, by the process about to be described. The juice expressed from the bruised leaves of the indigo plant, and exposed with a wide surface to the rays of the sun,

between the tropics, and thus evaporated to dryness, before any fermentation had taken place, acquired only a greenish blue colour; partly, as I think, because the basis of the indigo was but imperfectly oxygenated, and partly because it continued to be mixed with a yellow extractive matter, and a greenish resin, which are both naturally contained in the indigo plant, as M. Chevreul has ascertained; (see Ann. de Chemie, tom. 68.) though, by the common process of fermentation, and precipitation, the indigo is in a great degree separated from them, as well as from the other matters contained in its juice.

It would be a diviation from my subject, were I to give any account of the cultivation of the indigo plant: I may, however, be permitted to observe, that the species of the genus indigofera, most frequently employed, are first, —Indigofera anil, a large hardy plant growing wild in the hotter parts of America, and affording indigo of good quality.—

2. I—— Tinctoria; which, according to Loureiro, grows spontaneously, as well as by cultivation, in China, Cochinchina, Hindostan, Coromandel, and other parts of India, whence it was carried to America. It is called indigo franc, by the French, and is less hardy, though more productive than the other species.

3. I— Disperma; this I consider as the species called guatamala indigo, which yields a fine pulp, but is less productive than the preceding; and

4. I—— Argentea. This is called indigo batard, by the French; and, as Linneus says, was also a native of the East Indies. All these are suffruticose plants, or under shrubs; and they all have a peculiar smell, which is offensive to cattle.

The stems, with their leaves being cut, (which is best done when the plant is in full blossom,) are placed in large vats, called *steepers,* and pressed down by planks and wedges: in some places this is done immediately after being cut; in others, after being more or less dried;* an operation, which probably facilitates the solution and extraction of the indigo basis; as the falling of rain upon *hay,* is found to deprive it of a greater portion of its nutritious parts, than *grass* recently mowed, would have lost by the same means. Being properly placed in vats, the leaves and twigs are covered with water; which has hitherto been most frequently

* In a MS. relating to the manufacture of indigo, belonging to Sir Hans Sloane's collection, in the British Museum, (No. 4020, of Ayscough's catalogue) I find it asserted, that in some parts of the East Indies, they collect the leaves of the indigo plant, into great heaps, and leave them to grow hot and sweat, before they are steeped. In Egypt they grind the plant, after it has been soaked an hour in water of the temperature of 70° of Reaumer, or 190° of Fahrenheit, by which the extraction of the indigo basis is facilitated, but the broken parts of the plant afterwards become mixed with the indigo, and render it impure.

employed *cold*: and when this is done, the appearances which follow, are thus described, by Dr. Roxburgh.*

"In a few hours, more or less, according to circumstances, a slight motion begins to pervade the body of the liquor in the vat; the bulk increases considerably, with some additional heat; air bubbles are generated, some of which remain on the surface: these gradually collect into patches of froth; a thin violet, or copper-coloured pellicle, or cream, makes its ap-

* As a supplement to the former edition of this volume, I was induced to publish (with some observations of my own) an abstract of a MS. which had been put into my hands at the East India House, containing an "account of a new species of *nerium*, the leaves of which yield indigo," &c.; with a second part, containing "*the result of various experiments made with a view to throw some light* on the theory of that beautiful production: and an appendix containing a botanical description of a second new indigo plant; the whole illustrated with drawings, and addressed to the Honourable Sir Charles Oakley, governor, and president in council at Fort St. George, to be transmitted, to the Court of Directors of the united East India Company, and committed to their protection," &c. By William Roxburgh, M.D. But as the whole of that MS. with some few additions and explanatory engravings, has been lately, (and in some degree upon my suggestion) printed as a part of the 28th volume of the Transactions of the Society of Arts, Manufactures, and Commerce, I am enabled to abstain from a republication of my former abstract, though I shall at the proper places, avail myself of the most interesting of Dr. Roxburgh's facts; taking them from this last-mentioned volume of the Society of Arts, &c. to which my references will be made.

pearance between the patches of froth; soon after, the thin film which forms the covering of the bubbles that compose the froth, begins to be deeply tinged with fine blue. The liquor has from the beginning, been acquiring a green colour, and now it will appear, when viewed falling from one vessel into another, of a bright yellowish *green*, and will readily *pass the closest filter*, until the action of the air makes it turbid; a proof that the base of the colour is now perfectly dissolved in the watery menstruum: this is the time for letting off the vat. If suffered to remain, the bulk begins to disminish, and returns to its original dimensions; however, the fermentation continues; there is still much intestine motion through the vat, and large quantities of froth are formed. Hitherto the peculiar *smell* of the plant has prevailed, but now it becomes very offensive, something like that of animal matter beginning to putrify. As fermentation goes on, the *smell* becomes more and more offensive, and the quantity of airs discharged less and less, until absorption takes place."

This first macerating and fermenting *process*, occasions an extraction of the indigo basis, and an imperfect oxygenation of it: but in other respects I do not know that it is of any importance, to the production of indigo. Other plants, in similar circumstances, would ferment

with an evolution of carbonic acid gas; and doubtless the various extractive matters of the indigo plant, participate and co-operate in producing the appearances just described by Dr. Roxburgh; who has, however, ascertained that in the *first* part of this process, there was *a great absorption* of, or from the atmosphere; (the free access of which was indispensably necessary to the fermentation) and this absorption doubtles consisted principally of oxygene. He found, moreover, that as soon as the bulk of the mass began to be enlarged, a disengagement of airs took place, which he describes as being *fixed*, pure, and impure," (meaning, I presume, carbonic acid gas, oxygene, and perhaps hydrogene.) " But, continues he, about the time that the bulk of the vat is greatest, the fixed air is discharged purer, and in larger quantities than at any prior period." " I tried," he adds, " every means I could invent, to detect the volatile alkali, that I was led to expect, but without the smallest appearance of success, at any time." If, as soon as the fermenting liquor becomes green, an alkali be added to it, a precipitation, says *M. Dutrone*, will take place, " d'une fecule verte extremement belle"; and at a more advanced state of the process, which he calls " la fermentation putride," alkalies, according to his account, will precipitate a " fecule qui porte une couleur bleu de ciel trés le gere."

The fermentation being completed, the green coloured liquor is drawn off, from the steeper, into the *beating vat*, or receptacle, (which the French call *batterie*,) where it is violently agitated, commonly by machinery, during one, two, or three hours, according to the means adopted, and the force with which they are employed; the effect of this agitation is analogous to that of churning, for by promoting a farther oxygenation of the basis of indigo, it renders the latter *insoluble*, in the liquor, which had previously held it, dissolved; and thereby causes it to granulate, or collect into small particles, or little floculæ, *suspended, but not dissolved*, in the aqueous menstruum which still retains, in solution, the other matters extracted from the indigo plant, and by so retaining them, enables the manufacturer to separate the former from the latter, by adding lime water, or some other suitable *precipitant*, which is to be mixed with the liquor, as soon as a *distinct* granulation becomes manifest.*

* Dr. Roxburgh has believed, that the basis of indigo, during the fermenting process, was held in solution by carbonic acid, and that agitation and precipitants were afterwards useful, the former by *extricating* this acid, and the latter by *absorbing* it. That such effects are produced, may be presumed by the discharge of carbonic acid gas, which is manifest during the agitation of the liquor, and by the cessation of that discharge, when either lime water, or caustic alkali is added. But that this agitation answers another, and more important end,

During this last *agitating*, or oxygenating process, "fixed air, says Dr. Roxburgh, continues to be discharged, with pure and impure airs; but still nothing like volatile alkali." But when the precipitant is added, "from that instant an absorption of air takes place; and after the liquor has settled a little, a candle will burn freely close to its surface."

The most efficacious precipitants hitherto employed are pure well-burnt lime water, and the different alkalies, especially when in their caustic state;* and some of these in suitable proportion

may be proved even from some of Dr. Roxburgh's experiments to be presently noticed; and that lime water may act as a *precipitant, otherwise* than by absorbing carbonic acid, is certain, from its well known power of throwing down many colouring matters, when they are held in solution, where no carbonic, or other acid is present; in such cases the lime acts by its particular affinity for these colouring matters, in the same way in which, as Dr. Roxburgh observes, "a solution of tin in aqua regia (in a very small proportion) gives a large produce of light blue precipitate," when added to the liquor in question. Alum acts in the same way, but by throwing down at the same time the other extractive matters of the plant, it debases the quality of the indigo.

* Concerning the expediency of *precipitants*, Dr. Roxburgh delivers the following opinion: "The coloured liquor, impregnated with the first principles of the drug, (its base) whether acquired by fermentation, or by a scalding heat, will, without the least of our assistance, if only exposed to the open air, and particularly if with a large surface, in a short time begin to part with its colour, which will fall to the bottom in minute

being well mixed, and the liquor left at rest for six or eight hours, the blue-coloured matter will commonly be found to have all subsided to the bottom, leaving the supernatant liquor of a clear brandy, or Madeira wine colour: when it appears more or less green, or olive-coloured,

grains of fine blue indigo: agitation will hasten the separation and precipitation *much*, and cause the produce to be larger. Heat has nearly the same effect, though in a less degree, except when joined with agitation, in which case the two act more powerfully than either alone. The indigo procured by these means is good, if the process has been properly conducted; precipitants are not therefore absolutely necessary for the production of indigo, but if well chosen, and in a proper proportion, they forward the operation *much*, causing a larger produce than could be had without them; and I have reason, from a variety of experiments, to say, that the quality is by no means injured in consequence."—Dr. Roxburgh thinks lime water preferable to any other precipitant; alkalies, he says, "answer the best when made caustic, but even then lime water gives a purer indigo, though probably not in quite so great a quantity." He adds that if lye perfectly caustic be added, before the liquor has been agitated, or before any granulation has taken place, the extractive matters of the plant will generally be precipitated first, in the form of a dirty pale yellow fecula: in the mean time the supernatant liquor gradually acquires from the surface a deep blue colour, soon becoming turbid, and lastly the blue precipitate of real indigo will be formed over the first." P. 281, and seq. Precipitants, therefore, should not be added to the liquor until the indigo basis has been sufficiently oxygenated; which, among other appearances, may be known by a change in the colour of the froth on its surface, which, after appearing *blue*, becomes *colourless*, because the blue matter which gave it that appearance being no longer dissolved, *subsides* from the froth.

we may conclude the separation and precipitation of the indigo have been but imperfectly performed: this happens indeed but too often, and Dr. Roxburgh conceives "it to be owing to the presence of fixed air, (carbonic acid gas) still adhering to, and keeping dissolved a portion of the base" of indigo. I think it more probable, however, that a part of the basis of the indigo is, in such cases, hindered by the presence of carbonic acid, from attracting and uniting to itself a sufficient portion of oxygene to cause a separation of it by precipitation from the other extractive matters yielded by the plant; it having been found, that by renewing the agitation, of such green or olive-coloured liquor, and adding precipitants to it afterwards, more indigo may be obtained.*

* As the profit of the indigo maker greatly depends upon his knowing when to stop the fermenting, as well as to the agitating, process, it may be proper that I should subjoin a few observations upon each.

The fermentation begins soonest when the weather is hottest, and when the vat has been recently employed for the same purpose; as it then retains a kind of fermenting leaven. If the fermentation be stopped too soon, a considerable part of the colourable basis will be left unextracted, and *lost* in the plant: to avoid this loss, handfuls of the twigs and leaves are frequently drawn from the vat, that it may be ascertained whether they are become of a *pale yellow*, and the young tops made tender. Regard should also be had to the colour of the liquor, which, so long as the fermentation has been deficient, will have only attained a yellowish green, with a copious greenish froth, capa-

Dr. Roxburgh ascertained by experiments, which are minutely described at pages 278—281, of the volume before mentioned, that some

ble of being easily dispersed by a few drops of oil, which is not the case when the fermentation has been carried too far. In this last event, the froth or scum generally subsides, and the green colour of the liquor will lose its brightness, appear brownish on the surface, and become turbid, from an excessive dissolution and extraction of the various matters belonging to the plant. The liquor which has suffered in this way, cannot bear much agitation afterwards, without farther injury to the indigo resulting from it; which will become either blackish or of a dull *slate* colour, and be found very little susceptible of either granulation or precipitation; and even with moderate agitation, the liquor which has undergone this excessive fermentation will never afford good indigo. But where the fermentation has, on the contrary, been *deficient*, though the quantity of indigo to be obtained will be small, the quality may be improved by a greater degree of agitation. When too little of this last is given to liquor which has not been fermented sufficiently, the indigo will manifest a coarse grain, and not only prove less in quantity, but its blue colour, instead of the coppery gloss, will retain a greenish cast. I will here add, in regard to the precipitants, that the Javanese, as M. de Cossigny relates, avoid the want, and use of them, by first fermenting the indigo plants, and then *boiling* the liquor for a little time before it is agitated. It is not, I believe, the practice to put water a second time upon the indigo plants in the fermenting vat, in order to extract or wash out, any remnant of the indigo basis, left in, or adhering to the plant, after the fermented liquor has been drawn off; but I am persuaded, that if this were done, and this washing, or second extract, were added to the first, a considerable portion of indigo might be obtained, which I believe to have been hitherto lost.

of the green indigo liquor, taken, when just fit to be drawn off from the fermenting, into the agitating vat, and impregnated with carbonic acid gas, (in Dr. Nooth's apparatus,) would afford no granulation or precipitation of indigo. This was also the case with liquor obtained by scalding the leaves of the indigo plant in large earthen bottles. The liquor thus obtained, always became of a yellowish green, and the bottles containing it, being inverted in a large vessel of water, the liquor remained *unchanged* for a month; but, being taken out, and *atmospheric air freely admitted* to the liquor, *greenish blue veins were observed to spread, from the surface downward, until the whole became blue;* and then a precipitation of indigo soon commenced. This experiment was often repeated with the same result; and Dr. Roxburgh justly infers from it, that carbonic acid is not the agent, by which the colouring matter of indigo "is separated from its menstruum." Some of the same green liquor, being impregnated with nitrogene, from iron filings, and diluted nitrous acid, (in Dr. Nooth's apparatus) a violet-coloured film was produced, after some hours; but no other change took place, until the admission of atmospheric air, when the usual granulation and precipitation of indigo, soon followed.

Some of the same green liquor, being impregnated, in the same way, with hydrogene, from

iron filings and diluted sulphuric acid, it " was quickly covered with much of a deep violet-coloured scum, but no decomposition took place, till the atmospheric air had obtained access to the liquor, when it quickly became of a deep greenish blue, and let fall a considerable proportion of precipitate, which, on drying, turned out to be the most beautiful indigo."

In addition to these experiments, Dr. Roxburgh tried repeatedly, with the same green liquor, admixtures of lime water, volatile alkali, caustic lye, stale urine, prussiate of potash, &c. and they all concurred, says he, to " prove clearly, that the most powerful precipitants, added to these liquors, *cause no decomposition, without the help of the open air.*"

Though Dr. Roxburgh had thus ascertained, *the indispensable necessity of something,* obtained from the *open air,* to produce a granulation, and precipitation of indigo, and though he had also ascertained that this *thing,* could not be either carbonic acid gas, or nitrogene, or hydrogene, or ammonia; he did not suspect it to be oxygene, until the former edition of this, my first volume, had fallen into his hands; then however, (as I had predicted) he, with laudable candour, relinquished his belief of the supposed agency of *phlogiston,* in producing these effects; and declared himself convinced, that " oxygene is the colouring principle of indigo."*

* The following is extracted from a letter written by Dr.

M. Berthollet seems not to have well understood the effect of some parts of the process lately described. He says, tom. ii. p. 42, that

Roxburgh, to Robert Wissett, esq. and dated Calcutta, 29th of October, 1797.

"I have seen the heads of my essay on indigo published, and commented upon, by Dr. Bancroft. In consequence of seeing so good an use made of it, I am encouraged to send to your care, by Mr. Brown, the surgeon of the Albion, a package of a colouring drug, which I do not imagine has ever reached Europe, viz. the coloured tubes of the blossoms of *Nyctanthes* arbor tristis, of Linnæus. The Hindoos use them to give a most beautiful orange colour to cotton cloths; but with them the colour soon fades. I will thank you to give the parcel to Dr. Bancroft, and also beg of you to inform him, that *I am now a convert to his opinion,* viz. *that vital air, or oxygene, is the colouring principle in indigo.*—The *hot water* process begins to be used over these provinces, by some of the best manufacturers; with it they can make indigo, *when the weather is too cold* for the usual process of fermentation, and it gives a more beautiful and lighter indigo, like the guatamala, or fine Spanish flora. I send you a sample of some made by Mr. Pope, of Cossimbuzar, a most valuable farmer."

When Dr. Roxburgh was lately in Europe, he obligingly left with me, not only samples of the indigo here mentioned, (and which is truly excellent,) but of many other sorts, manufactured in different ways, from different kinds and species of vegetables yielding indigo, and with different precipitants, &c.; all serving either to confirm or illustrate particular facts respecting this interesting subject: but a distinct account of them would occupy too much space.

The scalding, or "hot water process," mentioned in the preceding extract, had been previously recommended by Dr. Rox-

the atmospheric air does not appear to intervene or partake in the fermentation, because there is a discharge of inflammable air. But it was fully ascertained by Dr. Roxburgh, that a copious *absorption* of air from the atmosphere, did occur; and that oxygene did combine with the basis of indigo, in a considerable degree, during the fermentation, was manifested by the *progressive change,* which as usual con-

burgh, and is, indeed, absolutely necessary to obtain indigo from the leaves of the nerium tinctorum, which affords none by fermentation, with water moderately warm. It is employed, as the Doctor informs us, by "the natives throughout the northern provinces or Circars," (of Coromandel) and "in many parts of the Carnatic," in making indigo from the common indigo plant. Among the advantages stated to result from it, are,—First, that, of a more complete and certain extraction of the basis of indigo, (by thus subjecting the plant to the action of water, heated to about 150°, or 160°, of Fahrenheit's scale,) than can be expected by the fermenting process; with which the plant, as M. de Cossigny asserts, (Treatise on Indigo, p. 145,) will yield indigo, upon being fermented a *second* time.—Second, that of not injuring the health of labourers employed in it; the carbonic acid gas, and putrid miasma exhaled by it, being much less than by the fermenting process.—Third, that of requiring less agitation; because the heat employed, greatly promotes the absorption and combination of oxygene.—Fourth, that of completing the operation, much sooner, so that it may be performed two or three times daily, upon a large scale.—Fifth, that of affording indigo, which dries quickly, without acquiring any bad smell; and which "has never that flinty appearance common to fermented indigo; but in softness and levity is like, or even superior, to Spanish flora."

stantly took place in the *colour of the liquor*, during the fermentation, until it acquired a full green, and even blueish colour, the froth or scum becoming more or less blue, at the same time; this change was not unknown to M. Berthollet, but instead of ascribing it to the *oxygenation* of the indigo basis, he supposed it to result from the separation, or destruction of a *yellow* substance, which gave the plant a greenish tint; thus intimating, that the indigo had existed naturally of a *blue colour in the plant*, which certainly is not the fact.

Some of the manufacturers of this commodity, in the East Indies, have lately purified their indigo, by taking it immediately from the small dripping *vats*, and boiling it in copper vessels, with water and fossil alkali, (soda) and afterwards carrying it to what are called the dripping *tables*, to undergo the treatment usually employed for bringing it to the form of dry cakes. In this way those impurities which *soda* can dissolve, will be separated; but others, on which it has no action, will remain. For these Dr. Roxburgh, as well as M. de Cossigny, have recommended the application of a diluted sulphuric acid, which is said also to brighten the colour;† as indeed it might be expected to do,

† Among the samples of indigo, with which I was favoured by Dr. Roxburgh, are three extracted from the *guatamala* indigo

in the way that the colour of indigo dissolved by it for the *Saxon blue*, is brightened. Probably the *diluted* acid, here recommended, will not be capable of diminishing the colouring matter of indigo, by dissolving and removing any part of it: but if there were any danger of this, it would be advisable to substitute the muriatic acid, which could have no such effect, upon the *indigo itself*, though it is equally effi-

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plant, produced by seed, furnished by Colonel Kyd; and they are stated to have been made on three successive days, viz.

On the first, 104lbs. of leaves and shoots were cut at *sun-rise*, and by the usual process, they yielded six ounces, $\frac{1}{277}$ of very beautiful indigo; i. e. at the rate of one ounce from about 17 lbs. of leaves and shoots:

On the second day, 64lbs. of leaves and shoots, also cut at sun-rise, yielded in the same way, four ounces $\frac{1}{276}$ of very fine indigo, or at the rate of one ounce from less than 16lb. of the leaves and twigs. This indigo was washed with diluted sulphuric acid, and three several times afterwards, with hot water; and though the produce was largest, the colour was a little the brightest:

On the third day, 56lb. of the leaves and twigs were cut at *noon*, the sun having shone upon them several hours; they produced in the same way three ounces $\frac{1}{299}$ of pure indigo i. e. one ounce from about 19lb. of leaves and twigs. This indigo was, I believe, intrinsically the best, but like that of the first day, was *not washed*; and the colour, though very beautiful, was in brightness a little inferior to that of the second day.

Considering that the leaves and shoots were cut at noon, on the third day, when the rays of the sun might be expected to cause an exhalation of much aqueous vapour, it is surprizing that so little indigo was obtained.

cacious, in dissolving all other matters likely to be mixed with indigo. It is, however, doubtful, whether any considerable advantage would result from these applications: they could add nothing to the *tingent power* of the indigo, though they might improve its *appearance*; but even this could not be done without such a diminution of its weight, as would counterbalance the latter advantage, and in general dyers know how to avail themselves fully of the tingent particles of indigo, whatever extraneous matter it may contain.

Besides the several species of indigofera, already mentioned, and the Nerium tinctorium, (respecting which I must refer to Dr. Roxburgh's publication, in the xxviiith vol. of Transactions of the Society of Arts, &c.) there are several plants which possess the basis of indigo, though the characters of some of them have not been well ascertained. This latter observation, however, is not applicable to a plant lately found by Dr. Roxburgh, to afford indigo, and by him denominated indigofera cœrulea, (*carneeli* of the Telingas,) of which, he has also given a minute description in the volume just mentioned; and from the leaves of which, says he, "I have often extracted a most beautiful light indigo."*

* I have now before me seven specimens of indigo, given to me by Dr. Roxburgh, and made by him from the indigofera

There is, moreover, a plant, belonging to a very different class, first mentioned as producing indigo, I believe by Mr. Marsden, in his History of Sumatra, p. 78, under the name of *taroom akkar*. He describes it "as a vine, or creeping plant, with leaves four or five inches long, *in shape like* (those of) *a laurel*, but finer, and of a dark green colour;" he adds, that "by reason of the largeness of the foliage, it yields a greater proportion of sediment." This plant Dr. Roxburgh considers as a species of *asclepias*, or swallow-wort, and has added to it the trivial or specific name of *tinctoria*. It appears to be nearly related to the nerium; both belonging to the natural order of *contortæ*, and both yielding their colourable matter from the leaves, most copiously, by hot water.* It was brought from Sumatra, and widely distributed in

cœrulea, with the help of *hot* water, to extract the *colourable* matter. They are similar to the same number of samples which the Dr. sent in 1793, with a description of the plant, to Mr. Ross, at Madras, to be forwarded to the Court of Directors of the India Company, and are all very fine blue or violet indigo; particularly four of the seven, which in appearance and effect, are, in my judgment, equal to the finest flora of guatamala.

* Dr. Roxburgh has favoured me with three samples of indigo, which he obtained from the asclepias tinctoria, by hot water; one is a very fine violet-coloured indigo; another is more inclined to blue, and the third to purple; the two last were specifically a little heavier than the first; the worst of them, however, would, I think, be considered as worth 8s. per pound.

Bengal, about the year 1791; is perennial, and easily propagated by layers, slips, or cuttings. I mention these particulars, because I shall have occasion to refer to them presently, in regard to a substance denominated barasat verte.

Professor Thomas Martyn, mentions the galega tinctoria, as being the plant from which the inhabitants of Ceylon prepare their indigo, which yields a *pale* blue dye (see his edition of Millar's Gardener's Dictionary.) He also mentions, on the respectable authority of Loureiro, that the spilanthus tinctoria, is cultivated in China, and Cochinchina; that the leaves bruised, yield a most excellent blue colour, and a green, prepared by a method more easy than from indigo, and not inferior in brightness.

Linnæus says, the Swedes obtain a blue colour from the scabiosa succisa, by treating it like the isatis tinctoria, or woad plant; and I have been informed, that the cheiranthus fenestralis, or cluster-leaved stock gillyflower, is also capable of yielding indigo. This may be easily ascertained.

Besides plants of the genus of indigofera in Africa, we have reason to believe there are several belonging to other genera, capable of producing indigo. Dr. Winterbottom says, "there is now no room to question that the blue dye, commonly used by the natives of the *windward coast*, is not indigo, but is obtained from a very different plant." He adds, "a few

roots of it, I am informed, have lately been planted within the settlement (of Sierra Leone,) so that an accurate description of it may soon be hoped for." Probably, this is the plant to which Professor Afzelius alluded, when, upon his return from Sierra Leone some years ago, he told me he had discovered a new plant producing indigo, of which he intended soon to publish a description. Dr. Winterbottom also states, on the authority of M. Isart, (Reise nach Guinea) that on the gold coast, the negroes, instead of the indigo plant, infuse "the leaves of a species of bignonia, and the root of a species of tabernæmontana, with a lye of wood ashes, to dye cotton blue." See his account of the Native Africans, vol. i. p. 97. The amorpha fruticosa, and the sophora tinctoria, Lin. also afford coarse sorts of indigo.

This production often differs greatly in regard to its specific gravity, some indigo being lighter than water; and the lightest being always, and justly, the most esteemed; because it is always the purest; excepting only when the comparative weight has been increased, by very *forcibly pressure*, to separate the water, and accelerate the drying, that it may not be in danger of becoming mouldy.* Indigo is some-

* Quatremere Dijonville asserts, and I believe truly, that indigo closely packed, and secluded from atmospheric air, will soon become hot, and undergo some degree of fermentation,

times adulterated, by fraudulently adding to it various gummy, resinous, earthy, and mucilaginous matters, and particularly an extract from the fruit of the embryopteris glutinifera, denominated *gaub* in the East Indies. It is also rendered both heavier and less pure, by employing lime too copiously, as a precipitant, which not only subsides, mixed with the indigo, but also throws down many other useless matters. This also happens in a greater or lesser degree with other precipitants, when used in excess, and more especially with alum.

Indigo also differs in regard to its colour, e. g. the guatamala, which has long been the most esteemed of all the varieties of American indigo, is divided into three sorts; of which the first, called by the Spaniards *flora*, has a very fine blue colour; the second, which bears the name *sobré salliente*, is violet; and the third, named *corte-color*, is copper-coloured. When the first of these is sold at 9s. the pound, the second is commonly thought to be worth 7s. and the third 5s. 6d. Of the East Indian indigo, that of Java was formerly most esteemed, but since the manufacture of this commodity has so much

by which white specks will be formed within the cakes of indigo. See his "Analyse et examen Chemique de l'Indigo, &c." Mém. des sçav. etrang. tom. ix. Indigo in drying should always be shaded from the sun, and a free current of air be made to pass over it.

engaged the attention of the British inhabitants in that part of the world, indigo superior even to that of Guatamala, has been imported, in considerable quantities, from the British possessions there : And of this, the finest blue commonly sells 20 per cent. higher even than the finest glowing purple, (though the last probably contains nearly as much colouring matter as the first,) and 70 or 80 per cent. higher than the best copper-coloured. The price has, I believe, also, been sometimes affected in this country, by the size and form of the indigo cakes ; the large and square selling for more than those which are flat and thin, and these last for more than broken indigo, though it must all be broken and powdered, before it can be advantageously used.

M. Berthollet has proposed to ascertain the comparative values of different parcels of indigo, by dissolving equal portions of each in sulphuric acid, and afterwards destroying their colour by adding the oxymuriatic acid to them, severally, always considering that indigo as most valuable, which requires the greatest portion of oxymuriatic acid for the extinction of its colour. But probably the relative quantity, and value of colouring matter, in any parcel of indigo, might be as well measured, or ascertained, without employing the oxymuriatic acid, by mixing a certain portion of the

indigo, when dissolved by sulphuric acid, with a certain quantity of water in a glass, and comparing the depth, or fullness of its colour, with that of other indigo treated in the same way, and taken as a standard or point of comparison. But, after all, there will be so much inequality in the different pieces or cakes of indigo, as it is commonly assorted, in any one package, that considerable uncertainty must attend any method of ascertaining its true value, by trials with small parts, or samples only.

The most accurate analysis of indigo, with which I am acquainted, is that recently made by M. Chevreuil. He took for this analysis the best Guatamala indigo, and found that by *digestion in hot water*, it yielded to the latter, ammonia, indigo at the minimum of oxidation*

* What is here called indigo at the minimum of oxidation, ought to be rather considered as the *basis* of indigo; for while it is susceptible of dissolution, either by water, or alcohol *alone*, it does not possess the properties, nor strictly deserve the name of indigo, though capable of acquiring the former, and deserving the latter, by a sufficient addition of oxygene. The existence of this basis, or of indigo at the minimum of oxidation, in the best Guatamala indigo, proves the difficulty of thoroughly combining the former, with its *full proportion* of oxygene by the usual process; and if it be thus contained in Guatamala indigo, how much more of it will have been left suspended and lost in the beating vat, as commonly managed? M. Berthollet mentions, probably from personal observation, that in Egypt, the indigo making process is so badly conducted, that the indigo produced by it, is always *greenish*, (" verdatre") and gives a bad colour; and that it is so much disposed to dis-

combined with ammonia, a particular green matter, in union with ammonia, gum, and a small quantity of yellow extractive matter; amounting all together to 12 parts for every 100 of the indigo employed. From the remaining 88 parts he obtained by digestion with alcohol, 30 parts, consisting of a green matter, a reddish resin, and a little indigo. By digesting the residuum with muriatic acid, he obtained 6 parts of "*resine rouge*," 2 parts of carbonate of iron, and 2 parts of red oxide of iron, in union with alumine, after these had been all separated, there remained about 3 parts of siliceous earth, and 45 parts of *pure indigo*. This last, but no other part, was capable, when burning, of emitting that *beautiful purple smoke*, by which indigo is peculiarly distinguishable; and which consists of indigo, rendered volatile by heat, without any decomposition. He concluded from this analysis, and from other experiments, that indigo may be purified "par la voie seche,* and par la

solve by fermentation, that the dyers need only mix a little *brown* sugar with it in the vat, to excite one, sufficient to render it fit for dying. An effect which could only result from a deficient oxygenation. See Elements, &c. tom. ii. p. 41.

* The pure part of indigo may be all converted to vapour, without any decomposition, by an elevation of temperature, a little *below* the point at which it would be decomposed, *and the simultaneous* application to its surface, of *a current* of any elastic fluid, which exerts no chemical affinity upon the indigo.

voie humide;" that when purified, it is susceptible of volatilization and crystallization: and that, when most purified, its colour is *purple*, rather than *blue*. (See Ann. de Chemie, tom. 68.) I think it probable, however, that this purple appearance results from a greater condensation of the colouring matter of indigo; since that of Prussian blue, when most pure, exhibits a similar purple coppery aspect.

Bergman after separating, as far as he was able, the extraneous matters mixed with indigo, found that 100 parts of it left 47, which he considered as its colouring matter, very nearly in a state of purity; and this being carefully distilled by itself, yielded 2 parts of carbonic acid, 8 of an alkaline liquor, 9 of an empyreumatic oil, and 23 of charcoal; which last, being burnt in the open air, left 4 parts, of which about one half was an oxide of iron, and the remainder a fine siliceous powder.

Bergman supposed the *blue* colour of indigo, to result from a combination of iron with the colouring matter of the plant, as the colour of ink does from the union of that metal with the colouring matter of galls, and that of Prussian blue from its union with the prussic acid.

This, however, will be most advantageously performed, with but small quantities of indigo; for in larger, it will suffer a *partial* decomposition, if kept for any considerable time, at such a temperature as is necessary to render it volatile.

But these supposed analogies are without any foundation; for the proportion of iron is not only by much too small to produce such an effect, but it possesses no affinity for the basis of indigo, nor the least power of influencing, or contributing to its colour.

M. de Chaptal, (who as a minister and a chemist, has manifested a great superiority of intellect, and of science,) appears to think, that in the fermentation of indigo, charcoal greatly contributes to produce its blue colour; "la dissolution des vegetaux, (says he,) donne un charbon d'un tres beau bleu, et il est probable, qui lorsque la couleur bleu est developpée par la fermentation, le carbone est presque mis a *nu*, et qu'il reste en combinaison avec une huile, qui ajoute a la fixité de la couleur, et indique le dissolvant le plus convenable." (Chim. appl. aux Arts, tom. ii. p. 406.) But if this reasoning were just, why is it that so few vegetables can be made to produce indigo, though all of them contain the basis of charcoal; and what becomes of the supposed charcoal, when by depriving indigo of its oxygene, in the way which will be hereafter explained, the basis of it, dissolved and secluded from atmospheric air, is rendered *colourless*, and *pellucid*, until by the re-admission of oxygene, its colour is reproduced? Certainly there is no instance in which charcoal has been rendered colourless by an abstraction of oxygene, and

afterwards black, by the re-union of it. Probably, the only similitude between charcoal and indigo, is that which I formerly pointed out; i. e. that in each, the basis combines with oxygene, and thereby acquires colour and stability; with a complete *indissolubility* in the former, and a very difficult solubility in the latter. But as their bases are different, so re their respective colours, and several of their other properties.

The colouring matter of all sorts of indigo, is nearly the same, and capable of giving nearly similar shades of colour, when the basis has been sufficiently, but not excessively oxygenated. The impure, or extraneous matters, mixed with it either unavoidably, or fraudulently, are many and various; and they may be generally dissolved or separated, by the means employed by M. Chevreuil; but when this has been done, there are very few chemical agents, capable of acting upon the residual pure colouring matter of indigo, duly constituted. There is, indeed, but *one* way, in which it can be dissolved, without injuring its basis, and diminishing the stability of its colouring matter; and this is, not by any *single* agent, but by the *co-operation* of several: of these, the first are such as by possessing a greater affinity for oxygene, than that which is exerted by the basis of indigo, are enabled to *deoxygenate* the latter, or at least deprive it of a great portion of its

oxygene, so as afterwards to render it soluble, by means which otherwise would be incapable of acting upon it; particularly lime, and the several alkalies, in their caustic state.

The matters employed to deprive indigo of its oxygene, and thereby render it soluble, are either vegetable, animal, or mineral. The vegetable are chiefly such as excite, or promote, fermentation; and indigo seems to have been exclusively employed with these, for some time after it was first made known, for dying in Europe. Until that period, blue colours had only been dyed by the woad, as I have already mentioned; and it being erroneously believed, that the colours of indigo, if employed *by itself*, would prove fugitive, it was in some countries totally prohibited, in others only permitted to be used when mixed with about one hundred times its weight of woad, in what was called the woad-vat. This was, and continued to be, the case in France, even under the enlightened administration of Colbert, and afterwards until the year 1737; when, in consequence of the experiments and representations of M. Dufay, a new regulation was issued by the French government, permitting the dyers to employ indigo either alone, or with woad, at their option. The preparation of the woad-vat, under the name of Cuve de Pastel, was minutely described by Hellot, (Art de la Teinture, chap. 10,) as it has been

since, more correctly, by Quatremere, Berthollet, Chaptal, and others; it is, besides, so well known to practical dyers, that a particular account of it from me cannot be wanted by them, and it would be superfluous to my *other* readers, who need only to be informed, that the woad is brought to ferment by first pouring over it a boiling decoction of weld, madder, and bran, and by keeping it afterwards in a suitable temperature, until blue veins appear on the surface of the liquor. Quick lime is then added to it, and also the proper quantity of indigo, finely ground with a small portion of water; the mixture is then well stirred, and afterwards covered over; and such other means are employed as may be necessary to keep up the proper, and only the proper, degree of warmth and fermentation, until a sufficient *deoxygenation*, and solution of the indigo, has taken place; which may be known by the blue or shining coppery colour of the liquor on its surface, (where the indigo is constantly revived by an absorption of oxygene) and by its *green tint* every where below the surface. With these appearances, the liquor will be fit for dying, and though the colour which it gives to wool or cloth will be *green*, when first taken out of the dying liquor, it will very speedily become blue, when exposed to the air, by attracting and regaining the oxygene taken from it during the fermenting process;

the abstraction of which was the cause of its green colour.

It has hitherto been found extremely difficult to attain the proper, and only the proper, degree of fermentation, in conducting the woad-vat, and this difficulty seems to have resulted principally from the *ever varying properties* of the woad, as it has been commonly and ignorantly prepared. Indeed, there is good reason to believe, that it would be much better if the manufacturers of this article would wholly abstain from giving it any sort of fermentation, *(which at best is certainly unnecessary)* and content themselves with barely grinding the plant, and drying it as expeditiously as possible, forming it into balls at the proper time. Much also depends upon the quantity of lime employed; not only for the purpose of dissolving the indigo, but also for that of moderating the fermentation; which, when excessive, induces a putrefactive process, and destroys the tingent power both of the isatis and indigo. Too much lime, on the contrary, obstructs the necessary degree of fermentation; the colour of the liquor then becomes blackish, and the vat remains useless, until the obstacle has been overcome, by the addition of matters, suited to counteract this excess. This vat, or preparation of indigo and woad, is very generally employed for dying wool and woollen cloth or stuffs.

Indigo is moreover dissolved, without any admixture of woad, in a vat which Hequet d'Orval et Ribaucourt, Berthollet, and others, have described under the name of Cuve d'Inde, or Indigo-vat; and which is also well known. For this the indigo being ground with a little water, its deoxygenation is produced by bran and madder, (acting as vegetable ferments,) and its dissolution by potash. This is liable to fewer failures than the former vat, but it is more costly, and is chiefly employed to dye silk. When fit for use, the surface of the liquor exhibits a blue scum, intermixed with patches of a shining coppery colour, and the mass below the surface appears of a fine green.

The only vat in which animal matters are made to co-operate in the deoxygenation of indigo, is that with urine, now but little used, except as a domestic dye for small woollen articles; madder, or some other vegetable ferment, is commonly added to assist in abstracting the oxygene, and, when this is done, the ammonia, or volatile alkali, of the urine, produces a dissolution of the indigo.

The influence of *mineral* agents in the deoxygenation of indigo, is yet more obvious and interesting than that of animal or vegetable ferments; and the former are, therefore, advantageously employed by dyers and calico printers, in fixing the colour of indigo upon linen and cotton. Of these the principal is the oxide of

iron, *at a low degree of oxygenation*, as it exists in the sulphate of that metal. Dr. Priestley appears to have first noticed the powerful attraction exerted by this sulphate, or by the oxide recently precipitated from a solution of it, upon the oxygene of the atmosphere, though its use, in promoting the dissolution of indigo, had been previously discovered by dyers, but without their having had any suspicion of its mode of action.

Indigo moistened, and finely ground, being put into warm water, with twice its weight of sulphate of iron, and the same quantity (as the latter) of pure lime, recently and well burnt, will, with a little stirring, be dissolved in twenty-four hours. In this mixture, a part of the lime unites with the sulphuric acid, forming calcareous sulphate, or selenite, and at the same time precipitates the oxide of iron, which, not being saturated with oxygene, attracts so much of that which was combined with the indigo, as to render this last soluble by the lime in excess, above that which was required to saturate the sulphuric acid. The beginning dissolution of the indigo, may be perceived by a shining copper-coloured pellicle, which forms itself on the surface of the mixture, while the liquor itself becomes green, and afterwards gradually inclines more and more to the yellow, as the solution advances. When it is completed, and

the liquor settled, the cotton yarn or stuffs are to be dyed in it: they appear yellow when first taken out, but by absorbing the oxygene, will rapidly assume and pass through the different shades of green, and in a few minutes become blue; the oxygene regenerating the indigo, in the pores of the cotton.

Mr. Haussman, of Colmar, in Alsace, who, with a considerable stock of chemical knowledge, daily practises the arts of dying and calico printing, published an excellent "Memoire sur l'Indigo, et ses dissolvans," in the Journal de Physique, &c. for March, 1788, in which he observes, that the change of colour from yellow to blue, in cottons dyed as beforementioned, may be greatly accelerated, and the blue rendered deeper and brighter than it would otherwise become, by plunging the dyed cottons, when first taken out of the vat, into water soured by vitriolic acid, which hastens the regeneration of the indigo, and moreover dissolves and carries off a portion of white calcareous sulphate, or selenite, which would otherwise diminish the intensity of the blue colour.

If the colour of the vat be not all used, soon after it has been prepared, it will require occasional stirring; since the dissolved indigo, by continually absorbing oxygenous gas from the atmosphere, will be constantly revived upon the surface of the liquor; and, when so revived,

it can only be re-dissolved, by being again subjected to the combined action of lime, and oxide of iron: if by length of time these should become perfectly saturated with oxygene, and carbonic acid, before the blue colour is all used, a farther portion of each must be added, and somewhat more of lime than of the sulphate of iron.

It must be observed, that where lime is the *only solvent* of indigo, as in the vat last described, the colour is not sufficiently condensed for dying very deep blues; and, therefore, when these are wanted, it is found best to increase the power of the lime by an addition of potash, or vegetable alkali, not exceeding in weight twice the weight of the indigo to be dissolved.

In calico printing, when different shades of blue are to be produced in the same piece, the indigo finely ground with sulphate of iron, and properly thickened, is first printed on the calico, which after drying, is put alternately into lime water, and then into a solution of sulphate of iron, in different vats, until by these means a sufficient abstraction of oxygene is made by the latter, and a sufficient dissolution of the indigo by the former, to fix the colour permanently. This is called China blue, and M. Chaptal mentions it as an instance in which the colour is applied before the mordant. But it seems to me that there is no *mordant* in this

operation which has for its object, *nothing but a dissolution of the indigo*, which being dissolved, fixes itself by simple application.

Mr. Haussman observes, that all the precipitates of iron, whether obtained from solutions of that metal by the mineral, vegetable, or animal acids, will serve, with quick lime, to dissolve indigo, as well as that of green vitriol, provided, and so long as they retain the property of absorbing vital air; but that a nitric solution of iron, or the rust of it, or any other preparation, where it exists in an ochrous form, not attracted by the magnet, nor capable of attracting pure air, will be wholly useless towards producing a dissolution of indigo, even though employed with an excess of quick lime, or of caustic alkali.

Mr. Haussman further observes, that caustic alkali, with fine iron filings, instead of the precipitate from copperas, would not dissolve indigo; but that (regulus of) antimony, brought into the form of a powder, dissolved it perfectly with the caustic alkali, or quick lime slacked by water; though the calces, or oxides of antimony, in this way, produced no such effect: nor did any precipitates of copper: on the contrary, they all seemed rather to hasten the regeneration of indigo, after it had been dissolved by some other means. This effect of the oxides of copper, (which results from the great facility

with which they relinquish their oxygene) is now well known, and calico printers avail themselves of it in making what are called *reserves*, or applications of verdigrese, sulphate of copper, or tobacco-pipe clay, and glue, or in its stead, tallow, mixed and printed upon particular parts, intended to be hindered from imbibing the indigo blue, and kept *white*, while the rest of the piece is dyed. After mentioning this effect, it can hardly be necessary to add that when the sulphate of iron is wanted to *deoxygenate* indigo, care should be taken that it be not mixed with any oxide of copper.

I have repeated most of Mr. Haussman's experiments, with different precipitates, or oxides of iron, and with effects nearly similar to those he describes. I found that neither the rust of iron, nor the nitric oxide of it, would assist in the dissolution of indigo; obviously because they were both already saturated with oxygene: I also found, that even the oxide precipitated from sulphat of iron, failed, and for the same reason, when, instead of separating it by lime, it was obtained by dissolving the sulphate in water, and leaving it for some weeks exposed to the air in warm weather, where the iron was farther acted upon, and saturated, as well as precipitated, by the oxygene which it gained from the atmosphere.

It is upon the same principle, that the *topical*

indigo blue, employed by calico printers, chiefly with the pencil, is made, only substituting for the sulphate of iron, a portion of red* orpiment, (sulfure of arsenic) which has a similar power, when dissolved by an alkali, of depriving indigo of its oxygene, and thus rendering it soluble. The ingredients of this composition are by different persons, mixed in different proportions, and will succeed with considerable latitude in this respect; indeed, the variable qualities of indigo, render it difficult to prescribe any exact proportions, which shall be always equally efficacious.

Mr. Haussman mixes twenty-five gallons of water, with sixteen pounds of indigo, well ground, (or a greater or smaller quantity, according to the quality of the indigo, and the depth of colour wanted,) to which he adds thirty

* *Red* orpiment produces a better effect than the *yellow*, because it contains less oxygene. The *fact* was known long before the *cause*. Until lately it was supposed, that the red and yellow differed only by containing different proportions of sulphur; and that this difference enabled one to act more efficaciously than the other, in the deoxygination of indigo; but this is not true. When orpiment is employed in this way, the alkali precipitates the arsenic in its *metallic* form, depriving it, at the same time, of a part of its sulphur. After which, the metallic arsenic acts upon the indigo, in the same way as the oxide of iron does, when green vitriol is employed, and by sufficiently abstracting the oxygene of the indigo, enables the caustic alkali to dissolve the latter.

pounds of good carbonate of pot-ash, placing the whole over a fire; and as soon as the mixture begins to boil, he adds, by a little at a time, twelve pounds of quick lime, to render the alkali caustic, by absorbing its carbonic acid. This being done, twelve pounds of red orpiment are also added to the mixture, which is then stirred, and left to boil for some little time, that the indigo may be perfectly dissolved; which may be known by its giving a yellow colour, immediately upon being applied to a piece of white transparent glass. M. Oberkampf, proprietor of the celebra'ed manufactory at Jouy, near Versailles, uses a third more of indigo; and others use different proportions, not only of indigo, but of lime, potash, and orpiment; which all seem to answer with nearly equal success; but with the best violet-coloured Guatamala indigo, it is certain that a good blue may be obtained from a less quantity than that prescribed by Mr. Haussman, by using as much recently burnt pure lime, as of indigo, the same quantity of orpiment, and twice as much potash. This composition is to be thickened by gum, which should be dissolved in it whilst hot; and it should afterwards be kept secluded as much as possible from the access of atmospheric air.

Indigo dissolved in this way, for penciling or printing, I shall hereafter call *topical blue*—its

strong tendency to attract oxygene from the atmosphere, and to be thereby regenerated, renders its use subject to many difficulties; it being almost impossible to pencil, and more so to print therewith, a piece of cotton throughout of the same shade, whatever pains may be taken to apply it equally, and quickly, by the most expert and careful hands.* It will give a fast colour, only so long as it continues yellow, or, at most, of a yellowish green; as soon as it appears blue, the indigo may be considered as revived, and incapable of fixing itself on the cotton: in this case, however, it may be re-dissolved, by adding more caustic alkali and orpiment. The clear liquor only, when gummed is to be used; but it is not to be separated from the sediment, which helps to preserve it in a state of dissolution.†

* Being at Manchester in 1795, Messrs. Hoyle and Son, shewed me in confidence, a method, of their invention, for printing calico, with the *topical* blue, expeditiously and successfully, by employing cylindrical rollars, and feeding them with the blue, through small perforations made at the *bottom* of a close receptacle for it, placed immediately over the upper roller, and extending the whole width of the calico, to which the colour was applied before it could have time to absorb oxygene. I believe this invention is now known to others, and that I may therefore mention it without any breach of confidence.

† I cannot discover when, or by whom, orpiment was first employed to promote the dissolution of indigo. In some

In making the before-mentioned composition, a copper-coloured pellicle appears on the surface of the liquor as soon as the indigo begins to dissolve; and this pellicle becomes violet, and at last blue, by longer exposure to the atmosphere. Mr. Haussman observes, that the same pellicle arises, with the same appearances, if the solution of indigo be put into contact with pure vital air; but that, under the receiver of

MSS. with the perusal of which I was lately favoured, and which appear to have belonged to the late Dr. Lewis, author of the Philosophical Commerce of Arts, and to contain some of the materials employed in that work, I find it noted, in what I consider as the Doctor's hand-writing, and under the date of 1734, that certain *linen* printers (calico being then but little employed in that way) had offered to give him one hundred guineas if he could "find out a way to print blue;" and that the writer agreed to attempt the discovery, if these printers would make him acquainted with the best means known to themselves of doing this, which they did, and their composition is stated to have consisted of equal parts of indigo, and quick lime, with half as much copperas, (green vitriol) and twice as much pearl ash. I conclude from this, that the use of orpiment, for the purpose under consideration, was then unknown, at least in this country, though sulphate of iron was employed, but in a proportion by much too small to produce its *best* effect. I find afterwards, an account of several experiments made by the writer, to accomplish what was desired of him by the linen printers, but the means employed by him for this purpose, were more likely to impede, than co-operate in the dissolution of indigo. So little was the subject then understood, that all reasoning upon it tended rather to mislead the reasoner, than conduct him to the truth.

a pneumatic machine, it diminishes in proportion as a vacuum is produced; and that, as might be expected, it does not appear at all, in either hydrogene, or nitrogene. He farther observes, that if, instead of orpiment, the sulphur and white arsenic, of which it is formed, be employed, together or separately, with quick lime and potash, no solution of indigo will take place; and this will also happen, even where orpiment is used, if quick lime be not employed to render the alkali caustic. That having put indigo, dissolved by orpiment, lime, and potash, into contact with oxygene gas, obtained by distillation from nitre, he soon found that excepting a little nitrogene mixed with it, the whole had been absorbed by the solution of indigo, and the blue rendered unfit for use, the indigo being regenerated. In this instance, he also found that a part of the alkali remained caustic, while another part of it had combined with the vitriolic (sulphuric) acid, (formed by the union of the sulphur to a part of the absorbed oxygene) and thereby produced sulphat of potash; another part of the oxygene, so absorbed, had combined with the arsenic, and changed its metallic form to that of an oxide, in which state it had united to the caustic alkali; and the rest of the absorbed oxygene had combined with, and regenerated the dissolved indigo.

Mr. Haussman was indeed inclined to explain the solution of indigo, according to the phlogistic system, by considering it as resulting from a greater affinity which phlogiston was supposed to have with indigo than with arsenic, and that it was the action of this phlogiston, joined to that of the caustic alkali, which operated the dissolution in question; but that the phlogiston, having still a greater affinity with dephlogisticated (or vital) air than with indigo, abandoned the latter as soon as the former was presented to it, leaving the indigo in its regenerated form; the alkali alone not being sufficient to preserve it in a state of solution. But a much happier, and more natural explanation of these effects, is afforded by the new doctrine, as already stated; and it is strongly supported by all that we know of the nature of indigo, and the properties of those agents which are employed to dissolve it.

Mr. Haussman found that the sulphuret of antimony (crude antimony) assisted in dissolving the indigo, for topical blue, as well as orpiment, but that it was unfit for penciling or printing, because the antimony being precipitated, in the form of a mineral kermes or golden sulphur, tarnished the blue colour, and adhered to the linens or cottons almost as strongly as the indigo itself; an inconvenience which I have also experienced. The oxide of antimony, with sulphur, did not produce a solution of the

indigo, when used instead of the crude antimony; though antimony, in its metallic state, (i. e. the regulus) reduced to powder, had occasioned the dissolution of indigo in the same way, and as well as the crude antimony. He found, however, that no such effect was produced by the filings of zinc; though when heated, this metal has great affinity with oxygene. He attempted in vain, to dissolve indigo, by a combination of sulphur with the other metals; and he attributes his want of success to the circumstance of their being dissolved with difficulty, or perhaps not at all "par la voie humide," in the caustic alkalies.

Besides repeating a great part of these experiments, and with nearly similar effects, I have made some, which, probably, were not attempted before; and several of them produced effects highly deserving of notice.

Having in 1791, attempted unsuccessfully to dissolve pure blue Guatamala indigo, finely powdered, by long and repeated boilings in water, with an excessive proportion of shell lime taken hot from the fire, and afterwards by renewed boilings with a copious addition of potash, I thought it might be worth while to try the oxide of tin, which had then, I believe, never been employed to promote the dissolution of indigo. It so happened that I had at hand nearly a pound of an oxide of tin, pre-

pared some time before, (for a different purpose) by putting two pounds of common single aqua fortis, diluted with as much water, upon a quantity of tin, not in very small pieces, and leaving the former to act slowly upon the latter during several months, until all its oxygene was exhausted; after which, I found the oxide, or calx, formed into lumps, and settled at the bottom. The clear liquor being decanted from the oxide of tin, the latter was slightly rinced with water, and being dried, remained in solid lumps. Some of these, weighing about twice as much as the indigo which I had found it impossible to dissolve, by the means just mentioned, were put into the caustic alkaline liquor, and in less than five minutes I perceived signs of a beginning dissolution, which increased rapidly, until the liquor had passed through all the shades of green, and become yellow, except at its surface, which was covered by a fine copper-coloured pellicle, of a shining metallic appearance. Silk and cotton dipped into the liquor, were taken out yellow, but quickly became green, then assumed a shining copper-colour, which afterwards changed to violet, and finally to a deep blue; which was found, by washing, to be permanently dyed. Part of the same liquor, gummed, and applied topically, answered as well for penciling as any topical blue I ever saw. Another part of it, being

poured into a white glass phial, so as, with a portion of the lime and oxide of tin, to fill it completely, (without gum) and being well stopped and left at rest, the mixture *in a few days became as pellucid and colourless as clean water*, excepting only the sediment at bottom.* Upon unstopping the phial, the *surface* of the liquor, by coming into contact with the atmosphere, and absorbing oxygene, instantly became first green, and then blue; and upon re-stopping the phial, and shaking it, the indigo forming this blue surface, was dispersed through the mass of liquor, and tinged it of a beautiful greenish yellow; but there being a sufficient quantity of oxide of tin unsaturated, the oxygene was soon absorbed, and the liquor again rendered colourless.†

When, instead of the oxide of tin, I employed

* I have, at p. 170, stated the basis of indigo to be *colourless*, when *wholly* deprived of oxygene, and of this, the fact just mentioned is a sufficient proof. Dr. Roxburgh has indeed said, p. 287, that "the indigo base is *naturally green*, while it remains dissolved in its watery menstruum, by which it was extracted from the leaves." In regard to this, however, I will only observe, that *wherever* the basis of indigo exhibits a *green* colour, it must be combined with a portion of oxygene, and this portion must be greater than that with which it is united in the yellow solution made for giving blue by *topical* application.

† Berthollet, tom. ii. p. 57, after mentioning my discovery of the use of the oxide of tin in promoting the dissolution of indigo, adds, "On peut dissoudre immediatement l'etain peu

the metal finely granulated, it produced no effect towards dissolving indigo; and on trying tin, which had been calcined with saltpetre in a crucible, I found that it not only did not dissolve the indigo itself, but prevented it from being dissolved by the oxide of tin (produced by the aqua fortis, as just mentioned,) or by crude antimony, or sulphate of iron, either singly or combined; indeed it was with difficulty dissolved, when orpiment, in a large proportion, was added afterwards; this I also found to be the case of tin, calcined alone in a crucible by strong heat: bismuth calcined in like manner, equally obstructed the solution of indigo. Probably in these cases the metals so calcined not only did not attract the oxygene of indigo, but let go some of that which they had imbibed during calcination.

In the course of my experiments upon indigo, I was induced to make trial of a large proportion of refined sugar, (instead of orpiment) and I found that it acted efficaciously in dissolving indigo, with the usual appearances, and producing a topical substantive blue, as permanent, and every way as good as any in use. I afterwards

oxidé, dans la potasse, et faire agir cette dissolution sur l'indigo : elle produit promptment une cuve ou les toiles se teignent en *bleu tres intense*." The formation of such a vat was naturally suggested, by the knowledge of what I had published on the subject.

tried coarse brown sugar, and I found it at least as effectual as the refined, for this purpose; it then occurred to me, that this might be a valuable substitute for orpiment, the use of which, as a constituent part of the topical blue, may, from its poisonous quality, sometimes produce mischief, and always gives the composition an unpleasant smell. I moreover conceived, that, by employing a large proportion of brown sugar, it might be practicable to thicken the mixture sufficiently for penciling or printing, and thereby avoid the greater expence of gum for that purpose; and upon trial, this also proved to be the case, the sugar thickening the solution sufficiently, and afterwards drying as expeditiously as when thickened by gum, contrary to what I had apprehended as probable, from recollecting that ink, when thickened by sugar, was disposed to retain moisture, and dry very slowly. I think, moreover, that when the solution of indigo is both made and thickened by brown sugar, in this large proportion, the latter, by being able to absorb a larger quantity of oxygene from time to time, enables the topical blue to bear exposure to the atmosphere somewhat longer, without a regeneration of the indigo, than when it is dissolved by only the usual proportion of orpiment. I conclude, therefore, that this way of composing a substantial topical blue, by employing coarse brown sugar instead of orpiment and gum, is deserving of particular atten-

tion, as forming a composition free from all poisonous qualities, and at the same time cheaper and better than that generally used. Molasses will serve as well as brown sugar to promote the dissolution of indigo; but I think not so well to supply the place of gum in thickening the composition.*

Sugar used in this way, seems to act like orpiment in combining with oxygene; which it is strongly disposed to do in other circumstances. M. Berthollet, in the second volume of the Annales de Chimie, mentions, that, in distilling the

* Since the former edition of this volume, I find that, according to Professor Pallas, the blue dyers of Astra can dissolve indigo, by boiling it in a lixivium of soda, with quick lime and clarified honey; which last appears to act like sugar in the deoxygenation of indigo. Dried raisins and figs, I have observed to produce a similar effect. Probably the most useful and inoffensive topical blue may be made by boiling powdered indigo with three times its weight of coarse brown sugar, in a caustic lixivium of soda and potash, and assisting the deoxygenation by adding the oxide of tin precipitated by lime from a solution of that metal by muriatic acid. If a muriate of tin be added to the topical blue, prepared with caustic alkali and red orpiment, or with caustic alkali and sugar, it will occasion a considerable effervescence, and at the same time produce a farther deoxygenation of the indigo, and thereby render the previous *greenish yellow* colour of the mixture almost white, and make the effervescing froth appear almost of the colour of milk, though even this froth, if speedily applied to calico, will attach itself, and by regaining oxygene, stain it with a permanent blue colour. Such an effervescence, however, is inconvenient, and I only mention the fact as an additional illustration of the theory before stated.

sulphuric acid upon different animal and vegetable substances, he found none of them so proper as sugar to form a large quantity of sulphureous acid; which it could only produce by its great affinity with oxygene.

I found, upon different trials, that, with the help of potash and lime, I could not dissolve indigo, either by sulphur, or white arsenic, or charcoal, or oxide of bismuth, or of lead (minium) or of zinc (lapis calaminaris,) or of manganese, or the alkaline solution of flints, or of the earth of alum, or by magnesia. I was equally unsuccessful with copper, in all the ordinary preparations of it: and indeed when verdigrise was added to indigo mixed with lime and potash as usual,—there was not only no solution, but the verdigrise afterwards obstructed the action of all other agents upon it, insomuch that the indigo remained undissolved, notwithstanding the combined action of crude antimony, orpiment, oxide of tin, sulphate of iron, and sugar, which were added in large doses, any one of which, with the quick lime and potash, would have effectually dissolved the indigo, had there been no verdigrise or oxide of copper in contact with it. The sulphate of zinc (white vitriol) was almost as adverse to the dissolution of indigo; for it not only did not contribute thereto, with potash and lime, but it hindered a solution from taking place, by the oxide of tin, crude antimony, sugar, and sul-

phate of iron, applied one after the other: though when to all these, a large portion of orpiment was added, and the mixture kept some time in a boiling heat, the indigo did at length dissolve, but with great difficulty and tardiness. The red sulphuret of mercury I found, on repeated trials, incapable of contributing, in any degree, to dissolve indigo with lime and potash; though it did not obstruct the dissolution thereof, when orpiment was added.

Wishing to know what effects would result from a stronger action of potash, lime, and orpiment upon indigo, I dissolved it with three times the usual portion of these agents, and having afterwards shaken the whole mixture well together, I filled a large transparent glass phial therewith (but without any gum,) and having secured it from all contact with external air, by a glass stopper covered with wax, I left it in that state for three months, shaking the phial occasionally, that the more fluid part of the mixture (which had become colourless) might be acted upon more equally by the lime, &c. at bottom; after which, the phial being opened, I found that the mixture (which with different proportions, had always given a deep permanent blue to cotton,) was become incapable of manifesting any colour by the contact of atmospheric air; the indigo having been not only deprived of the oxygene necessary to its colour, but probably

rendered incapable of re-uniting with it as formerly, in consequence of a decomposition of its vegetable basis, or a new combination thereof, with one or more of the agents in question, too intimate to be overcome by any of the usual means of regenerating indigo. Here we have an instance of one of the most permanent of colouring matters losing its colour irrecoverably; not by any thing like *combustion*, which necessarily requires the presence and combination of vital air, but by means which seclude it from, and deprive it of, all such air.

The topical blue, when made, is often applied by the pencil upon spots or figures previously dyed yellow, in order to produce a permanent green: but the caustic alkali contained in it, especially when employed too freely, seems to weaken the yellow on which it is laid. Wishing to remove this difficulty, I thought of neutralizing the alkali, at least in some degree, so as to make it harmless in this respect, without, at the same time, rendering the blue less efficacious. For this purpose I selected the muriatic acid principally, because as no oxygene had ever been ascertained to exist, as one of its constituent principles, there seemed to be no danger of its reviving the indigo, by imparting oxygene to the topical blue when mixed with it: and having made this mixture, the effect answered my expectation; for though it produced some effer-

vescence, it neither rendered the mixture blue nor even its effervescing surface, though covered with froth; but both remained green, while secluded from the contact of atmospheric air, by being inclosed in a vessel well stopped; and I found it practicable in this way to neutralize the alkali completely, without rendering the indigo unfit to produce a fast blue colour, or a green, when applied to yellows, if applied quickly; but when the topical blue, thus neutralized, had been kept some time, the indigo, being deprived of the alkali which had held it in solution, gradually subsided in a great degree, and became unfit to be applied topically. There is, however, I think, an intermediate degree to which the alkali may be neutralized, without precipitating the indigo, in any considerable quantity, at least for several weeks, and which will be sufficient to prevent the alkali from exercising any action injurious to the yellow colours upon which the blue may be laid.

The fluoric acid employed in this way answeredas well as the muriatic; and I now find this to be true of the sulphuric and some other acids; there being no danger, as from some former inaccurate experiments I had once supposed, of a revival of the indigo, by mixing either of them with the topical blue, the attraction of the basis of indigo, (in this preparation) for oxygene not being sufficient to decompose any of these acids,

so far as I know. Carbonic acid is always present in the topical blue without being decomposed; and no injury is produced by other acids when mixed with it, so long as, by not being decomposed, they are incapable of reviving the indigo. I have ascertained also that the oxygenated muriatic acid will not revive it: a fact which I once thought favourable to the opinion of Scheele and Davy, that it contains no oxygene; but the other facts just stated, shew that nothing decisive in that respect can be inferred from it.

It is to be observed, that all the preceding means of rendering indigo soluble, by abstracting a part of its oxygene, serve only to bring it back to the state in which it existed while dissolved, and retaining its green colour in the fermenting process, before its minutest particles had been collected together, in a concrete blue form, by agitation; and I have already mentioned, at p. 171, my persuasion, that the colouring matter of the indigo plant, in this fluid state, is not only fit for dying, but that the blue colour dyed with it, would, like that of the isatis, or woad, prove more permanent than that given by the indigo, after it has been made to assume a concrete form; because its basis, even by the least hurtful ways of dissolving it, will, I think, necessarily be in some degree weakened, as all other vegetable colours are found to be, by the action of such powerful agents as are requisite for that purpose;

and I think it probable, that the very durable blues which are given by particular people in some parts of Africa, owe their superiority to this method of dying.

According to Mr. Clarkson, "it is well known, at least in the manufacturing towns, that the African dyes are superior to those of any other part of the globe." "The blue (continues he) is so much more beautiful and permanent than that which is extracted from the same plant in other parts, that many have been led to doubt whether the African cloths brought into this country were dyed with indigo or not. They apprehended that the colours in these, which became more beautiful upon washing, must have proceeded from another weed, or have been an extraction from some of the woods which are celebrated for dying there. The matter, however, has been clearly ascertained: a gentleman procured two or three of the balls, which had been just prepared by the Africans for use: he brought them home, and upon examination found them to be the leaves of indigo rolled up in a very simple state.

Sulphate of Indigo.

The powerful action of sulphuric acid upon indigo, and the very bright lively blue colour thereby produced, had been observed by chemists long ago, but no person seems to have

applied this colour upon cloth as a dye, until about the year 1740, when it was done by Counsellor Barth, at Grossenhayn, in Saxony. In addition to the indigo and sulphuric acid, he employed crude antimony and lapis caliminaris, (and as some say alum) mixing them with the oil of vitriol first, and adding the indigo afterwards: but these additions being found useless, were after some time discontinued.

When a bit of pure flora, or blue Guatamala indigo is dropped into concentrated colourless oil of vitriol, in a flint glass phial, radiations of a bright greenish yellow may be seen almost immediately projecting from the indigo, and resulting from a solution begun upon its surface; and if the phial be left *unagitated*, these radiations soon become green, and afterwards blue, without any motion or change in their direction. This sudden conversion of the blue colour of the indigo, to a greenish yellow, seemed to indicate an abstraction of oxygene, as its cause; but it was difficult to conceive how such an abstraction could result from the application of an acid, already completely saturated with oxygene. I recollected, however, that Berthollet had mentioned, as one of the effects caused by the action of sulphuric acid upon indigo, that, of its determining (as it does with sugar) the production of a little water, in consequence of the intimate combination which it effects between

certain portions of the oxygene and hydrogene, which are among the constituent parts of indigo; a combination by which he accounts for the great heat, resulting from a mixture of powdered indigo with sulphuric acid, and the *non* production of *sulphureous* acid thereby. This fact, of the production of water by a combination of a part of the oxygene of the indigo, with a part of its hydrogene, enables us to understand how the indigo may, and, indeed, must be deprived of a portion of oxygene, sufficient to change its colour, suddenly, to a greenish yellow; and this change being effected, the progress afterwards, to green and blue, accords with the series of changes observed in the topical blue of the calico printers, after its application; and indicates a restitution of the oxygene, taken from the indigo by the formation of water. To ascertain with certainty whence this restitution was made, or rather whether any part of it was derived from the atmosphere, I placed a small piece of the blue Guatamala indigo in a phial, and filling it completely with colourless oil of vitriol, I closed it immediately with its ground glass stopper, which came in contact with the acid and indigo, (the latter from its levity rising to the top) so as to leave no space for air. I then placed the phial at the window, and keeping it motionless, saw, by transmitted light, streaks of

greenish yellow radiating downward from the indigo, and gradually changing and passing through all the intermediate shades of green, to a full sky blue; and as nothing could have been gained from the atmosphere during these changes, it was manifest that they must have been produced by something contained in the sulphuric acid; and as the latter does not appear in this operation to suffer any decomposition, nor the indigo to be capable of effecting any, I conclude, that when this last has been rendered soluble, by the *deoxygenation* resulting from a production of water, it enters into a triple combination with the oxygene and sulphur composing the acid, and thereby regains its blue colour, with additional brightness; either from its union with an increased proportion of oxygene, or from some effect resulting from the sulphur, which had not been combined with it originally. But though the colour is rendered much more beautiful by this *triple* combination, it is accompanied with a great diminution of its former stability, and differs *essentially* from the solutions of indigo made by lime and alkalies, assisted by the deoxygenating agents lately mentioned; for when indigo is revived or recovered after the latter mode of solution, it is found to possess all the properties which belonged to it before it had undergone any solution, including its original indissolubility, (except by the agents

already mentioned.) But after being dissolved by sulphuric acid, it can never be revived with its original and peculiar properties. It may, indeed, be readily precipitated by alkalies, but excepting a blue colour, the precipitate will differ from indigo, in every respect. It will no longer retain the power of emitting its characteristic *purple smoke*, when ignited; and it may be readily dissolved, by all the acids, and alkalies, as well as by other agents which previously had no dissolving power over it; and, though most of these solutions are blue, their colour has but little permanency, especially those made with pure alkalies, whether fixed or volatile, as they soon spontaneously become green, and finally colourless.

When the basis of indigo, after being sufficiently deoxygenated, is dissolved by lime or alkalies, it forms no permanent combination with either, and may afterwards be separated and recovered from them without having suffered any perceptible injury or change. But the effect is very different after this basis has been dissolved by any of the acids; probably it suffers least injury from the sulphuric, though with this, indigo can hardly be said to produce a fast colour, even on wool, since, as Haussman observes, it is easily extracted by soap in boiling water, and changed by alkalies to an olive colour, more or less yellow, according as the alkali is more or less caustic; and since the

adhesion of this blue to linen and cotton is so feeble, that cold running water will gradually carry it off.

Bergman, (whose labours have thrown much light on the subject of indigo) ascribes the want of greater permanency in the Saxon blue, to the use of sulphuric acid, not sufficiently concentrated. He used an acid whose specific gravity, compared to that of water, was as 1900 to 1000, and employed eight pounds of this acid, to dissolve one pound of indigo. I believe, however, that he was misled on this subject, and that Pœrner is much nearer the truth, when he says, that the best proportion for dissolving indigo, is only four times its weight of good pure oil of vitriol; and that where more is used, the blue is less permanent. I am even inclined to think that the blue will prove more durable, if this last quantity of acid be diluted, with an equal portion of hot water, as soon as the indigo is put to it, and the mixture left in a warm situation, 48 instead of 24 hours, for the indigo to dissolve; because, by a slower, and more moderate action, I think the basis of the indigo will be less weakened; at least I have frequently dissolved indigo in this way, and the colour has appeared to be more durable, than when it was dissolved by an undiluted acid.*

* If the indigo be *finely powdered,* it will be thereby ren-

The indigo being dissolved, Mr. Pœrner adds as many ounces of dried potash, as there were of indigo in the solution, which produces an effervescence; and after twenty-four hours, he adds eight pounds and a half of water, for each pound of oil of vitrol employed, and puts the whole into a glass vessel for use.* Instead of potash, I have used clean chalk, and this even in such quantities, as to saturate the vitriolic acid. The indigo was then precipitated with the chalk, and being collected in a solid mass, it was still capable of dying a blue on wool, though it took much more slowly, than in the ordinary way of dying Saxon blue; in which the colour applies itself so rapidly to wool or woollen cloth, as to render it difficult to prevent its taking unequally, a defect which might probably be obviated by a small portion of chalk. It is to prevent this inequality, that M. d'Ambourney advises, where deep Saxon blues are wanted, to pass the cloth at different times through vessels containing only what might

dered soluble, with a smaller proportion of the acid, and even that proportion may be more diluted.

* Pœrner says, and I think truly, that by this addition of potash, a more agreeable blue is produced, and that it penetrates farther into the cloth. He mentions as an instance of the abundance of colouring matter afforded by indigo, his having dyed five pieces of cloth, each weighing one pound, of different shades of Saxon blue, all with a single half ounce of indigo.

suffice for weak colours, in order that the blue may, by these partial applications, be made to take with more evenness. Silk, dyed along with wool, takes a much weaker colour, (I mean with the addition of chalk) because it has less affinity with the indigo, than wool has. This preparation of indigo, however, would not give a deep blue, because being united with so large a portion of white sulphate of lime, the blue colouring particles could not be sufficiently condensed for that purpose. Pœrner conceives the Saxon blue to be rendered more durable by previously preparing the cloth with alum, and sulphate of lime.

The solution of indigo by sulphuric acid, is usually called by dyers chemical blue. It ought, however, according to the new nomenclature, to be termed sulphate of indigo; a name by which I shall continue to distinguish it.* When applied to wool, the blue colour is much more permanent than it is in a fluid state; for though a little manganese, added to

* Pœrner describes a sulphate of indigo, which he prepared in a dry solid form, and reserved as a *secret*: he represents it as being more commodious, and advantageous for dying, than the common sulphuric solution of indigo. Berthollet conjectures (tom. ii. p. 97) that this may have been the precipitate which I had recommended, of sulphate of indigo, by an addition of carbonate of lime. It doubtless must have been a *precipitate* by this or other means.

the sulphate of indigo, instantly destroys its colour,* wool, which had been previously dyed blue with some of the same preparation, was not discoloured by the action of manganese, dissolved in sulphuric acid.

I do not know that a black was ever produced by the sulphate of indigo, or by any other preparation of that drug alone. Mr. John Wilson, who greatly contributed to improve the art of dying at Manchester, has asserted, that though a redundance of colouring matter, will increase the force and body of a colour, yet that no repeated dyings of blue will become black. I have, however, now before me, two pieces of cloth, one of which is the deepest and purest black perhaps ever seen, and it was dyed by me, very lately, from sulphate of indigo, em-

* The *destructive* action which manganese exerts upon the colour of indigo, when it (i. e. the manganese) is mixed with sulphuric acid, though weaker, resembles that of muriatic acid, after it has been mixed with manganese; and to my conception, affords a strong presumption, that in both mixtures, the destroying power depends upon a co-operation of something *gained* from the manganese; which is, however, contrary to the notion of Scheele and Davy, that muriatic acid, by its admixture with manganese, and conversion to oxymuriatic acid, *gains nothing*, but is merely deprived of the hydrogene previously combined with it; and that this deprivation constitutes the whole difference between the muriatic and oxymuriatic acids. Manganese added to the topical blue, soon revives the indigo, but does not injure its colour.

ployed alone, though in an unusual quantity; the other is a fine Saxon blue, which was cut off from the first, before it had taken up so much of the blue colour, as to become black. I lately found also, in making the topical blue, that a small piece of cotton, which I had thrown into the mixture, and which, being forgotten, had remained there forty-eight hours, was, when taken out, of a *full black*, so permanently fixed, that neither lemon juice nor alkalies seemed capable of impairing it. I could not, in one or two trials afterwards, succeed in producing a similar black on linen or cotton; and it must be remarked, that when I produced this, it was in a mixture to which I had at first put a little manganese, to see whether it would promote the dissolution of indigo; and finding it did not, I had afterwards added more than the usual proportion of orpiment; one or both of which additions, may have contributed to the black in question.*

* That Saxon blue, or the colour of indigo, in combination with sulphuric acid, depends upon the union of a certain proportion of oxygene, as in all other preparations of this drug, may be proved, by adding to the sulphate of indigo, a little muriate of tin, which, by its ordinary deoxidating influence soon changes the blue, first to green, and then to a pure bright yellow. If this yellow mixture be applied to linen or calico, it will dry without losing its yellow colour, the affinities of the oxide of tin, or of the muriatic acid, or of

The sulphuric acid, or oil of vitriol, as commonly prepared, contains a small portion of the nitric, which, however small, necessarily does some harm in forming the sulphate of indigo. M. Captal observes, that he has seen the colour fail, and the stuffs intended to have been dyed, spoiled by this fault in the sulphuric acid employed for that purpose, which ought, therefore, to be guarded against as much as possible.

The indigo of all others most preferred for Saxon blues, is the flora of Guatamala, which indeed is seldom employed for any other species of blue.

The other kinds, when mixed with oil of vitriol, effervesce sometimes very strongly, in

both, counterbalancing that of the indigo for oxygene. But if the linen or calico be moistened with a weak solution of carbonate of soda, or potash, to neutralize the acid, the yellow will *return* through all the shades of green, to the former Saxon blue. Muriatic acid *without tin,* produces no change in the colour of sulphate of indigo, because it has alone no deoxygenating power. Analagous to the preceding fact, (now first mentioned) is that published by Vauquelin, of the deoxygenating influence of hydro-sulphurated water, which when mixed in a close stopped phial with sulphate of indigo, soon becomes green, and in a few days yellow; but if the phial be afterwards unstopped the sulphate of indigo gradually returns through the different shades of green, to its former blue colour, as fast as the separation of sulphuretted hydrogene permits the indigo to recover its oxygene. An undissolved hydro-sulphuret will act more efficaciously in this way, so as to render the sulphate of indigo almost colourless; after which, if it be applied to calico, the latter will first become yellow, next green, and then blue.

consequence of the extrication of fixed air; the presence of which, may easily be accounted for, by recollecting that lime is commonly employed to accelerate the separation and precipitation of the minute particles of indigo, while in the vessels called beaters, and that in doing this, it subsides with the indigo, after having absorbed carbonic acid, which in this way is again set free by the oil of vitriol.

Here it will be proper that I should offer some conjectures on the cause of the different colours of indigo: and as a foundation for these, I must remark, that the flora, or blue indigo of Guatamala, is much lighter than the violet, and that this last is lighter than the copper-coloured. From the lightness of this *blue* indigo, and from its not effervescing with acids, when dissolved by oil of vitriol, there is the strongest reason to conclude that no lime is employed to accelerate the separation and precipitation of its colouring matter in the beaters; since, if there had been any, it would have increased the specific gravity of the indigo, and by absorbing carbonic acid, would necessarily have caused an effervescence, when dissolved in sulphuric acid; assuming, therefore, that no lime is employed to separate and precipitate the colouring matter, it would necessarily follow, that, to obtain such separation and precipitation, the agitation must have been continued longer than would other-

wise have been necessary, and the unavoidable consequence would have been, the combination of a larger proportion of oxygene, with the colouring particles so exposed to it, than that which takes place with those separated by lime: it will therefore follow, that indigo, obtained in this way, will contain a greater portion of oxygene than in the other; and it seems natural to conclude, that the blue colour is occasioned thereby. To ascertain, however, the justice of this conclusion as far as I was able, I took some of the lightest and bluest Guatamala indigo, and dissolved it by lime, potash, and orpiment, as usual; one effect of such solution, we know to be, the taking away from the indigo a considerable part, at least, of its oxygene; and I accordingly found, as I have done in all cases where indigo was dissolved for the topical blue, that the dissolution was accompanied with a bright shining copper-coloured pellicle upon the surface of the liquor, which of itself was of a greenish yellow underneath. The production of this pellicle may be easily explained by recollecting that the dissolved indigo, which has lost its oxygene, and become thereby of this greenish yellow, being at its surface in immediate contact with atmospheric air, regains a part of what it had lost, and by doing so, becomes copper-coloured; but swimming as it does upon a mixture disposed to attract oxygene, it cannot,

in this state, retain so much thereof as the indigo itself formerly had, while it was of a blue colour; and therefore, so long as the body of the liquor remains yellow or green, the pellicle covering it, will be only copper-coloured, though consisting of a colouring matter which was formerly blue, and which would have become so again, if, being dissolved, it had been thinly applied to linen or cotton, and brought sufficiently into contact with the oxygene of the atmosphere. As therefore this blue indigo had apparently become copper-coloured, only by having less oxygene than before, is there not from this circumstance, an additional reason to conclude, that the copper-coloured indigo, separated and precipitated by lime, is made of that colour, only by its possessing a smaller proportion of oxygene than the blue indigo? and whilst this *blue* indigo is preferred for combination with sulphuric acid, as producing least effervescence, we should expect that the copper-coloured, as being the least oxyginated, would be most suitable for the indigo vats, and for the topical blue, because in these the dissolution is effected, by taking away oxygene; and the less there is of it, the more easily will this be effected; and here the choice and practice of the dyers accord with my hypothesis, as they constantly employ the copper-coloured indigo for these last purposes.

Having already noticed all the *known* means or solvents by which indigo can be rendered useful in dying, I will only add a few observations concerning the effects of some other agents upon it.

If strong nitric acid be mixed with powdering indigo, its action upon the hydrogene of the latter will be so violent, as to produce actual combustion; and when diluted, its power, though moderated, will always prove destructive of all the useful properties of indigo, unless it be made so weak, as to manifest no sort of influence upon it. When it is of the strength of common or single aqua fortis, it dissipates a considerable portion of the component parts of the indigo, and converts the remainder into a rusty brown viscous bitter mass, which will burn and detonate, and which, according to Haussman, is soluble in alcohol, and also in water, when the proportion of the latter is very large. With a more diluted nitric acid, the indigo at first affords a bright yellow, but it soon changes to the rusty brown before mentioned; and the basis of indigo is then so completely decomposed, that the blue colour cannot be restored, by any of the various means which I have employed for that purpose.

The most concentrated muriatic acid, even with a boiling heat, has no action upon the pure colouring matter of indigo, though it dis-

solves some other parts of it; and this is true of the citric, tartaric, acetic, phosphoric, fluoric, and other acids.

A mixture of sulphuric, nitric, and muriatic acids, greatly diluted, will slowly dissolve powdered indigo, and change its colour to a very bright lively yellow, which appears to have considerable stability, though it could not be fixed on linen or cotton.

It is remarkable that though the strongest muriatic acid, even when boiling, has no influence upon the colouring matter of indigo, yet this, or even a much weaker acid, when it has been saturated by dissolving tin, will, if mixed with powdered indigo, in the common temperature of the atmosphere, speedily make it green, and afterwards yellow; holding a considerable portion of it suspended in the state of a yellow solution, whilst the residue subsides, as a powder of the same colour. In this case, the oxide of tin first produces a deoxigination of the basis of indigo, and thereby renders it soluble by the muriatic acid, to which it was before inaccessible. But being so dissolved, this basis either undergoes a decomposition, or enters into a new combination with the oxide of tin, or the muriatic acid, or both, of a nature so intimate, that no means which I have been able to employ, to remove or neutralize the acid, have enabled the indigo to regain its former portion of oxygene, or

return to its former blue colour; as the sulphate of indigo will do by such means, when it has been made yellow by muriate of tin.

The insolubility which the basis of indigo acquires by combining with oxygene, may, as Berthollet observes, be compared to that of certain metallic oxides, which at a maximum of oxidation, cannot be dissolved by acids, but are made soluble by the application of means suited to produce an abstraction of oxygene. And here I may terminate my explanation of the extraordinary and highly interesting chemical properties of indigo, believing that it will suffice to enable my readers to understand, both the reason and effects of the several methods and means employed to fix its colour, by dying and calico printing.

It now only remains for me to mention some facts respecting the history of indigo, which have been purposely kept back, because I believed they would be read with more interest, and be better understood when the properties of this drug had been previously made known.

Mr. J. N. Bischoff, in a work which manifests great reading on the subject of dying, ("Versuche einer geschichte der Färberkunst, 1780,") appears to think, that the indigo with which we are acquainted, was unknown to the Greeks and Romans; that the *indicum* of Pliny was not a dying drug, but a paint very different from

our indigo; and that the charter or contract which passed in 1194, between the cities of Bologna and Ferrara, respecting certain duties to be paid at the former city, upon the Grana de Brasile, (or Kermes) and upon indigo, alluded to the indicum of Pliny, and not to the substance now called indigo. It may, however, be demonstrated from the known properties of our indigo, and those which Pliny has distinctly mentioned as belonging to his *indicum*, that the former is an exact resemblance of the latter. After describing the preparation of a very costly fine purple substance employed by painters, (and obtained by skimming the vessels in which the Tyrian purple was dyed,) Pliny mentions, (lib. xxxv. c. 6.) the *indicum* as next in value and importance. "Ab hoc maxima autoritas *indico:* ex India venit," &c.—" cum teritur nigrum; at in diluendo misturam purpuræ cæruleique *mirabilem* reddit." After this mention of the country whence it was obtained, and of the admirable mixture of blue and purple colours which it exhibited by being diluted, he adds, that it had been frequently adulterated by pigeons' dung, and other fradulent mixtures; and then, with great sagacity, he points out a trial by which the genuine drug might always, and *certainly, be distinguished from the spurious;* and this was by putting it upon *live coals*; where, says he, the true indicum will *burn with a flame of the*

most beautiful purple tint. "Probatur carbone: reddit enim, quod *sincerum flammam excellentis purpuræ.*" I have already at p. 195, mentioned this purple flame, and the purple smoke accompanying it, as peculiarly distinguishing indigo. It was a *criterion* abundantly sufficient for Pliny's purpose, and the *only one*, which, in the then deplorable state of chemical science, could have been suggested by him. It is true that the Greeks and Romans, not knowing how to dissolve indigo, used it only in painting, but their ignorance did not alter its nature, or hinder it from being, as it must have been, the identical substance, with the uses and properties of which, we are now so much better acquainted. It is true, also, that Pliny was mistaken, not in regard to the place whence it came, but in regard to the way in which it was produced; he having supposed it to be a slime naturally collected in the scum of the sea, and adhering to certain reeds growing on its shores ("harundinum spumæ adhærescente limo"). And with this notion, he imagined that the peculiar odour of indigo, when burning, resembled the smell of the ocean, a circumstance which he says made some think it was gathered from the rocks ("dum fumat, odorem *maris* olet: ob id quidam e scopulis id colligi putant.") These notions, and the different names and circumstances, which were applied to this substance, or mentioned as con-

nected with it, by Dioscorides, Galen, Paulus Ægineta, and others, induced Caneparius, in his work "de Atramentis, &c." (p. 193) to adopt what he supposed to have been the opinion of the former, that two different colouring matters from India were known to the ancients, one naturally adhering to *reeds*, &c. as described by Pliny, but now, as he supposed, wholly unknown to the moderns; and the other, an *artificial* substance similar to our indigo, and which he supposed to have been extracted from the isatis, or *woad*, by boiling it in dying vessels, and collecting and drying the scum, or skimmings, (as Pliny had mentioned to be done to obtain a pigment by the dyers of Tyrian purple.) This he adds, is called in vulgar language, "*Endego*," and is brought by merchants from India to Alexandria, in Ægypt, and to Syria, and thence imported to this city of *Venice*, now become (says he) the *emporium of the whole world.**

* "Consequitur ergo ut,"—"duo atramenti Indici genere fuerent a Dioscoride constituta, (unum) eorum prodidit naturale quod sponte ab arundinibus in India paludibus, instar spumæ vi solis exiens humor concrescebat colore purpureo, *quo tamen prorsus caremus.* Alterum vero Indici genus scriptum nobis reliquit esse arte factum; dum enim in cortinis, hæc sunt vasa infectorum in quibus tingunt pannos, ebullit *glastum isatisve* herba dicatur, et vulgo *guado,* tunc efflorescit, innatatque spumma purpurea, quam seduli artifices detrahunt, et siccant." This, he adds, is "quod vulgus appellat *Endego,* corrupto voca-

This work of Caneparius, was printed in 1519, at *Venice*, (where he lived, and where dying was then more practised, and better understood, than in any other part of Europe:) and I adduce his testimony chiefly to correct an error into which M. Berthollet appears to have fallen, when (at p. 22, of the first volume of his Elements, &c.) he asserts, that the *first indigo* made use of in Europe, was imported from the East Indies by the *Dutch*.* The fact is, that for a considerable time before the first voyages of the Dutch, to the East Indies were made, indigo, in considerable quantities, had been imported through Egypt and Syria, to Italy, *and employed in dying*. That this was one of the uses of that which Caneparius mentioned, as being imported through those countries from India, is evident from his next page (194),

bulo; hoc a mercatoribus defertur ex India, Alexandriam Ægypti, et in Assyriam, demum ex illis partibus in hanc *Venetiarum* Civitatem *universi mundi Emporium advehitur*." That Caneparius was not accurately informed of the plant which afforded indigo, or of the method in which it was obtained, will surprize no one who is told that, according to Mr. Ray, botanists, even when he wrote in 1688, were not agreed on this subject, though the plant was suspected to be a leguminous shrub, belonging, or allied to the genus *Colutea*.

* "Il paraît meme que le premier, (indigo) qui ait été employé en Europe, nous a été apporté des Indes orientales par les Hollandais."

where, after noticing the fact, of its having been formerly employed as a medicine, he adds, that in his own time, it was *used by the dyers and writers;* that the former were accustomed to dissolve it in vats, with a lye of wood ashes, and other wares, according to their own practices, concerning which, says he, it is not my office to give instruction.* Caneparius was a physician, and not likely to have been minutely informed in regard to these practices; and yet, in the same page, he describes very accurately, the method of preparing, for dyer's use, the *isatis*, from which he believed the indigo to have been extracted,† and from which indigo may indeed be obtained.

I find among my papers, a statement, which

* "Usus igitur Indici est hodierno tempore *tinctoribus*, et scriptoribus: *nam dissolvunt eum tinctores* in Caleariis cum lixivio, et aliis more suo, hæc tamen vos docere non est meum institutum."

† "Isatis est herba, quæ ante florem colligitur, et sub mola tunditur, et facto ex ipsa cumulo maceratur soli, mox in magnos globos redacta, et sub tecto locata aspergitur aqua, ut magis, potiusque, maceretur tunc edit magnum fetorem, et nigrescit, et sic præparatio Isatis sive glasti dicatur idem est, perficitur ad tincturas," p. 194. The supposition of Caneparius, that indigo was obtained from the isatis, or woad plant, seems to have been prevalent even in this country, so late as 1640, when Parkinson, who was then treating of indigo, called it "Indico, or *Indian Woade.*"

I made some years ago, on the authority of Sir Hans Sloane, (and taken, as I believe, from his Natural History of Jamaica, &c.) importing, that the annual consumption of indigo in Europe, about the year 1620, (soon after the time when Caneparius wrote) amounted to 350,000lb; and that this came principally by the way of Aleppo, where it was computed to cost 4s. 6d. the pound. It is probable, therefore, that the Dutch had not then begun to import indigo, by the Cape of Good Hope; or at most, that they imported but very little of it. That it had previously, for a considerable number of years, been imported through or from Turkey, is evident from several facts, and among others, from Mr. Hackluyt's "remembrances for Master S——," who, in 1582, was going to Turkey, and, among other things, was instructed "to know, if *anile*, that coloureth blue, be a *natural* commodity of those parts, and if it be composed of an herb?" See Voyages, ii. p. 161. Ed. 1599.

Bischoff has, however, furnished decisive evidence to prove that the use of indigo in Europe, as a dye, was anterior to the first voyage made by the Dutch to the East Indies. He tells us, (Versuche, &c.) that the appellation or distinction of woad dyers, among the Germans, may be found in a charter, dated so early as the year 1339—that with these, certain Flemish and Italian

dyers, who had resorted to Germany, were afterwards incorporated under the name of ART, WOAD, and FINE Dyers: that they excited the jealousy and enmity, of a more ancient corporation, the black dyers; and as Indigo was employed by the former, the black dyers, influenced by this enmity, exerted themselves with so much success, in decrying this dying drug, that the Elector of Saxony, and Duke Ernst the pious, issued severe prohibitions against the use of it; and that even in the Diet of the Empire, it was described as a pernicious eating devil, and corroding dye stuff. "*Fressende Teufels,*" &c. and for these prohibitions of the Elector of Saxony, he refers to the Codex Augusteus, part 1, p. 236, under the dates of 1521 and 1547; and in regard to the opprobrious appellations applied to indigo in the Diet of the empire, he refers to a work printed at Frankfort, in 1577; all which dates are much earlier than any of the voyages of the Dutch to the East Indies.

In what way Indigo was first dissolved, or used for dying in Europe, I know not; but in the old collection of *recipes,* which I have mentioned in the introductory part of this volume, as translated from the Dutch, and printed in London, so early as 1605, I find one at p. 32, respecting the use of indigo, which is there called flora, or "*floray,*"* and directed to be fermented by the

* In the act of the 23d year of Queen Elizabeth, cap. ix, in-

vat process, with wood ashes, bran, and greening weed, (probably weld) and the appearances indicating the fitness of the fermenting liquor, to be

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digo is designated by the names of "*ancle,* alias *blue inde.*"— How long the vulgar Italian name of "*endigo,*" mentioned by Caneparius, had prevailed in that part of Europe, I am not able to ascertain; but it appears to have been afterwards adopted and spelt with exactly the same letters, in the account of Canche's voyage to Madagascar, and by other French writers of that time; and our name of indigo has manifestly been thence derived.— The Spaniards and Portuguese, who had found the way to India, by two opposite courses, at a much earlier period, and there became acquainted with this production, adopted the Hindu name of anil, and aneileira; and these are the nations by whom indigo was first manufactured in America, viz. by the Portuguese in Brazil, and by the Spaniards in Mexico, where they each recognized the plant growing spontaneously. It seems extraordinary, therefore, that professor Thomas Martyn should have erred, as he has done, in his recent edition of Miller's Gardener's Dictionary, by representing "nil or anil" as "the American name" of indigo, and concluding, that the Portuguese had borrowed their name from the Americans, not from the people of India.—Though the French and English were later than the Spaniards and Portuguese, in encouraging the manufacture of indigo in America, they afterwards made considerable progress in it. The former exported from the island of St. Domingo only, in 1774, 2,350,000lbs. weight of this commodity, and nearly about the same time in 1773, in the space of twelve months, 1,107,000 pounds weight of it, were exported from South Carolina. But in both places, the manufacture of this commodity has ceased, from new, though different circumstances. The deficiencies, however, which might have resulted from these changes, have been fully obviated by an increasing production of indigo in the East Indies. The importation and sale of this com-

applied to the stuffs to be dyed, are distinctly pointed out; especially that of its becoming *green*. How early this had been known, or how long this collection of recipes had existed in Dutch, or any other language, previous to the English impression in 1605, I cannot say; but there is, I believe, no reason to think that the Dutch had even then began to import indigo.

That this artificial production was first obtained from India, is proved by the testimony of Pliny, and other ancient writers, confirmed by a variety of circumstances; and particularly by its name, which is known, from numerous authorities, to have been *nil* in the *Hindu* language, from the earliest times, in which there is any authentic mention of it: and this name still continues to be

modity, at the East India house, in 1792, amounted only to 581,827lbs. whilst the importation into Great Britain, from other parts of the world, amounted to 1,285,927lbs. since which time the latter importation has gradually declined to less than a fourth of the former amount; whilst the importation from the East Indies, and sales at the India house in the year 1806, amounted to 1,811,700lbs. and produced in sterling money 1,685,275*l* and the importation and sale at the India house, in the following year, amounted to 5,153,966lbs. and produced the sum of 1,863,091*l*. sterling.—I have no accurate account of the sales of East Indian indigo since 1807. They may probably have diminished a little within the last year or two, because the obstructions to the exportation, resulting from the peculiar circumstances of the existing war, have considerably reduced the price of this commodity; the importance of which, as a dying drug, greatly exceeds that of any other.

given by the Hindoos, to all the plants whence Indigo is obtained by them; not excepting the nerium tinctorium, from which Dr. Roxburgh believed that no indigo had ever been obtained until his discovery respecting it. The late Sir Wm. Jones has however stated in the fourth volume of Asiatic Researches, that a Hindoo peasant, who brought this shrub to him, gave it the name of *nil*, which signifies blue in the language of that country. "A proof," adds he, "that its quality was known to them, as it probably was to their ancestors, from time immemorial."—When the Arabs and Egyptians afterwards obtained a knowledge of indigo, and of its use, (as they did of many other things) from India, they naturally adopted the name, with the substance itself; the Arabs calling it nil and nir, as Julius Scaliger long since mentioned, (in his book, on plants,) and the Egyptians giving it the name of nil, or neel. It is stated in the memoirs of the Baron de Tott, (p. 278,) that the seeds of the indigofera tinctoria, with which the Egyptians dye their only garment (a linen shirt) are imported *annually* from Syria; Egypt being a *hot-house* which *exhausts* the plant, before the seeds can ripen. The Egyptians, therefore, were not likely to be the first discoverers of a manufacture, depending on a plant, which could not yield *prolific* seed in their own country.

Concerning the history of the isatis, or woad,

I shall make but a very few observations. It was called by the former name among the Greeks, and particularly by Dioscorides; but it bore that of *glastum* among the Gauls and Germans; which, in their language, signified glass: hence Cæsar, in the 5th chapter of his 5th book, de Bello Gallico, says "omnes vero se Brittani *vitro* inficiunt, quod cæruleum efficit colorem: atque hoc horribiliore sunt in pugnæ aspectu."—Pliny distinguishes it sometimes by the Greek, and at other times by the Gallic names; and in the first chapter of his 22d book, he mentions it as resembling the plantain, and as being called glastum by the Gauls; and though he does not repeat Cæsar's observation, that the Britons made their skins blue with it, in order to appear more terrible in battle, he says, that their wives and daughters painted their bodies with it, when they appeared *naked*, at the sacred festivals, so as to resemble Ethiopians. He had previously mentioned, in the 7th chapter of the xxth book, that this plant was employed to dye wool.

But though the Britons in Cæsar's time appear to have cultivated enough of the woad to dye their skins, the inhabitants of this island at a later period, obtained it from abroad, to dye their *garments;* and, indeed, they are said to have depended wholly on the French for it, until 1576. But in 1582, Hackluyt remarked, that it was *then* brought to good perfection, (in this kingdom)

to the great loss of the French, our old enemies." (See Voyages, &c. vol. ii. p. 161. ed. 1599.) I do not find that the woad plant has ever been observed to give a blue colour to the milk of cows, like the indigo, which, when eaten by them, not only renders their urine blue, but, according to Dr. Garden, of South Carolina, the cream of their milk also became "of a most beautiful blue colour." See Phil. Trans. vol. l. p. 296.

Gardenia Genipa.

The *Genipa* Americana of Lin. has recently been united to the genus named Gardenia, by the late John Ellis, Esq. in honour of Dr. Garden, formerly of South Carolina. Swartz, on whose authortiy this change was principally made, has strangely represented this, as being only a shrub, though I have frequently seen the tree growing 50 or 60 feet high, with a trunk five or six feet in circumference. Its fruit, (the only part connected with this subject,) is technically denominated a *berried drupe,* nearly of the size and shape of a lemon, a little pointed, and umbilicated at the end, and covered by a skin, which, whilst *unripe,* is of a light ash colour, with a slight appearance of green: immediately under the skin, is a white solid fleshy substance, moderately suculent, about one third of an inch in thickness, surrounding a soft pulpy matter, of an oval

form, and about an inch in diameter, consisting of two cells, in which many flattened roundish seeds are nestled in rows.

If this fruit or berry, whilst unripe, be sliced or broken, and exposed to atmopheric air, its colourless substance, or the clear juice expressed from it, almost immediately acquires a strong deep blue colour, and is universally employed by the savage tribes of Guiana and Brazil, to stain their skins with a variety of spots, lines, and figures, for the purpose of ornament at their feasts and dances, as well as to render themselves *terrible* to their enemies when going to war; as the isatis, or woad, was employed by the Britons in Cæsar's time. But the most singular circumstance attending this application is, that no repetition of washing with soap, nor any other application, so far as I could learn at the several times of my being in Guiana, appeared to have the smallest power to remove the blue stains so produced, until after some days, (generally nine or ten;) when the epidermis, or scarf skin, by perspiration, rubbing, &c. appears to wear away, and make room for another, which is untinged; and it is in this way *only*, as I believe, that the stains in question spontaneously, and gradually disappear, after some days.*

* Since my last return from Guiana, I find it stated by Hart-

Oviedo seems first to have mentioned this tree by the name of xagua; but he describes the colour produced by its unripe fruit, as being *black*, adding that the stain given by it to the skin, cannot be removed in less than 10 or 12 days ; and that it never can be effaced from the finger nails, until by their growth or elongation the stained parts can be removed. Francis Ximenes afterwards mentioned the tree by the name *xahuali*, which it bore in New Spain, he says, the stain is only to be removed from the skin after fifteen days, and never from the nails, except by their growth and separation, as explained by Oviedo. Marcgrave, (Brazil. p. 90,) described the tree under the names of janipaba, and janipapa, by which the Brazilians called it, and from which the more prevalent name of *genipa*, was derived. He says, " immaturus fructus concisus, et cuti affricatus, tingit colore ex nigro sub cærulescenti, qui nullo modo ablui potest, sed post octo aut nona dies spoute evanescit."

Piso (at p. 138,) asserts, that the stain spontaneously disappears, not only from the *skin*, but from *paper* in about nine days, (tinctura

sinck, (" Besehryving van Guiana," i. 49,) that the acrid milky juice of the fruit of the *carica papaya*, or papau tree, will remove the stains in question ; which, if true, is a curious fact, and I regret not having been informed of it, whilst I had proper means to ascertain the truth *experimentally*.

enim illius corpori, vel *charta* illita circa nonam diem evanescit.") An assertion which has been often repeated, and generally believed, though it never had any better foundation, than a presumption, that because it did not remain on the skin, it would not remain upon paper; and hence it was concluded, that dangerous frauds might be practised, by writing with this colour instead of ink. Coppier had, indeed, made this assertion some years before, (" Historie et Voyages des Indes occidentales," printed at Lyons, 1645, p. 91.) And he pretended that the fact had been first discovered by himself, and that he had endeavoured to consign it to oblivion for the prevention of fraud. There was, however, no foundation for this pretension. I have now before me, both parchment and paper, on which I wrote with the juice of the unripe fruit of the tree under consideration, seven years ago, and it has not, as far as I can discover, suffered the smallest decay; and there is good reason to believe it would prove even more durable than the common writing ink, though it differs from it, by inclining much more to the dark blue colour. The *fable*, however, of the fugitive nature of this ink, and the dangerous purposes to which it might be applied, was so generally and firmly believed, by the inhabitants of the Essequebo and Demerary, that I was induced to report it as credible in

the volume, which, at an early age, I published respecting the Natural History of Guiana, in 1769.*

This tree, like the nerium tinctorium, asclepias tingens, &c. belongs to the *natural* order of *Contortæ*, and is known at Essequebo, Demerary, and Berbice, by the *Arrowauk* name of *launa*, and of Surinam by that of *tapouripa*, which undoubtedly was borrowed from some of the neighbouring tribes, probably the Carribees, with whom the first (English) settlers in that colony, had more communication than with any other; though I cannot find this name in

* Francis Ximenes mentions that tricks were sometimes practised with the juice of this fruit, by privately mixing it with rose water, and giving it to the ladies in New Spain; and Dutertre, in his Account of the French West India islands, writing of this tree says, "il porte le *fard* des chambrieres nouvellement venues." He adds that the simple maid servants, who, in considerable numbers, about that time, came to the West Indies from France, were told upon their arrival, that unless they washed their hands and faces with the (colourless) juice of this fruit, their skins would become *black*, and that, believing this, they eagerly collected and applied the supposed means of preserving their complexions, and were astonished, soon after the application, to find their faces and hands covered with a hideous dark blue stain, which nothing could remove for nine or ten days. He indeed mentions his having married considerable numbers of them, before this stain had been removed, and repeats the fable respecting the supposed frauds which might be practised by using the juice of this fruit as a substitute for ink.

any vocabulary of the language of that people. Mad. Merian, has mentioned this tree inaccurately, under the name of *tabrouba*, and has intended to represent a branch of it, at her 43d dlate, but has *transposed* the explanation, or description belonging to this plate, by joining it to her 48th plate, and connecting to the former, that which relates to the latter; a blunder which no person seems to have before noticed.

When this volume was first published in 1794, I believed, and stated my belief, that the blue colour of the fruit in question, like that of indigo, resulted from a combination of oxygene, with a vegetable basis; and in fact that it was similar to indigo. And this belief was principally founded upon my having, when at Surinam, 1770, applied the *colourless* juice of the fruit, to pieces of linen and calico, and seen the parts to which it was applied, speedily become blue, as happens with the indigo and woad plants; and upon my having found that the colour so produced was not discharged by repeated washings with soap, nor considerably injured by exposure to the sun and air for several days: my experiments at that time were, however, but few in number, and made under the disadvantage of being then but little acquainted with the subject of dying: wishing, therefore, for greater certainty respecting the nature and properties of this colouring matter,

I determined, when I visited Guiana a third time, in 1805, if possible, fully to investigate the subject. And accordingly having observed, soon after my arrival in Demerary, a young gardenia genipa tree growing on the plantation Reinsteen, then belonging to Messrs. Brummell and Addison, which tree, through probably bearing for the first time, exhibited two or three dozens of the berries or fruit, each about the size of a nutmeg. I informed Mr. Brummell of my wish to make experiments with them at the proper time, and with his usual kindness, he immediately ordered that they should be all carefully preserved for my use. In a few weeks after, I observed the tree to have shed all its leaves, (as happens to trees of this species at certain seasons,) and that it afforded the uncommon spectacle of a *leafless tree bearing fruit.*

About this time, circumstances connected with the state of my health, determined me to return immediately to Europe, by the way of Barbadoes; and having no leisure to make even a single experiment, the fruit of this tree, which had then almost attained its full growth, they were all gathered, and embarked with my baggage. But finding soon after my arrival at Barbadoes, that they were becoming soft, and in danger of spoiling, before I could conveniently make the experiments which I intended, I caused them to be sliced and dried in the sun; presuming that

they might afterwards be preserved several years, like the indigo plant, in a state fit for my experiments. But while this was doing, the sudden transition of the whole inner colourless substance of the sliced fruit, to a full dark blue, without any intermediate yellow or green tint, engaged my attention, as indicating an *important difference* between this, and the basis of indigo; for it was hardly credible that the affinity for oxygene, should be so much greater in the former than in the latter, as to enable it *at once* to become blue, without even the momentary appearance of an intervening green.

By the part which I took in slicing this fruit, my fingers were deeply stained; and as this stain might well seem *indecorous* to the gentlemen and ladies, with whose hospitalities I was daily honoured, I spared no pains to remove it, by repeated washings with soap, alkalies, &c. and by frequent applications of lemon, and lime juice, but without producing any sensible diminution of this troublesome dark blue colour, until it disappeared in the usual way, by an apparent abrasion of the cuticle.

I did not neglect, when in Barbadoes, to apply some of the juice of the sliced fruit, by which my fingers were stained, to pieces of calico, impregnated with alumine, and the oxide of iron, as well as to some which had no impregnation, and I afterwards found that neither of

these bases had any affinity for the colouring matter under consideration; it being in no respect changed thereby. The calico without any basis, had acquired a very dark blue tinge, which was not altered by washing with soap; nor by exposure to sun and air for some days; though in this respect it seemed to be less permanent, than I had believed it to be, from my former experiments in Surinam.

Since my return to London, I have made such trials as to me appeared suitable, with the sliced and dried fruit of the gardenia genipa, which, though more than seven years have elapsed, still retains a dark blue colour; but this manifestly depends on principles very different from those of indigo. For it is soluble both in potash and soda *alone;* and when lime and orpiment were added to these, *no* change of colour ensued (from blue to green,) indicating a susceptibility of deoxidation. Sulphuric acid seemed to brighten the blue colour as it does that of indigo. But (unlike sulphate of indigo,) *this mixture* appeared to have no affinity for vegetable substances, and so little for the animal, that cloth by long boiling in the *blue* liquor, would only receive a slight drab colour. Nor does the juice of the fruit seem capable of permanently staining the fingers, after it has already become blue. The addition, whatever it be, which occasions the blue, if made *before*

it touches the skin, rendering it incapable *afterwards*, of attaching itself either to animal or vegetable substances. Nitric acid changes the blue to yellow, as it does that of indigo.

Several writers have asserted, that the fruit of the gardenia genipa when *ripe*, becomes yellow, and loses its disposition to assume a blue colour. Whether this colourable property was in any degree affected, by my having kept the fruit in question, until it was approaching towards rottenness, (which might produce effects like those of ripeness) I know not; but as its blue colour evidently results from causes, differing greatly from those which produce the colour of indigo, it seems very desirable to ascertain their nature; though I think this can only be done by trials upon the *unripe and recently gathered* berries, which, while their juice remains colourless, might be placed, some *in vacuo*, others in the several gasses separately, and exposed to the sun's rays, as well as kept in *obscurity*, to discover which of these situations and agents contributed most, either to hasten or retard the production of the blue under consideration.

Brown, in his History of Jamaica, p. 143, observes, that " the pulp of the berries of the Randia aculeata, Linn. (called in that island the indigo berry, and which grows plentifully on the smaller branches of the plant,) is very thick,

and stains paper or linen of a fine fixed blue colour. I have tried it (continues he) on many occasions, and have always observed it to stand, though washed with either soap or acids; but it does not communicate so fine a colour with heat. It would prove (he adds) an excellent fixed blue in all manner of paints and prints, if it could be obtained in any quantity; but the berry is not very succulent, and the people as yet are not very industrious in these parts."

This plant, like the genipa, has recently been added to the genus *gardenia*, (under the name of gardenia aculeata,) and it is remarkable that their generic characters being similar, their fruit also should yield *blue* colouring matters, which, as far as I know, seem to resemble each other. The indigo berry, in like manner, belongs to the *natural* order of *contortæ*, which more than any other, contains plants yielding the *blue* colour.

Mr. Martin Lister (in the VIth Vol. of the Philosophical Transactions, page 2132,) mentions that "the seed husks of glastum sylvestre, old gathered and dry, being diluted with water, stain a blue, which, upon the affusion of lye, strikes a green, which green or blue, being touched with the oil of vitriol, dyes a purple; and all these colours (says he) stand." Some of the mushrooms also becomes blue, when exposed to atmospheric air. The same effect, according

to Sennebier, happens to the milky juice of the tithymalus euphorbia, Lin.

It is mentioned somewhere in the Swedish Memoirs, by Cronsted, that the stalks of the polygonum fagopyrum, Linn. by fermentation in water, afford a blue which did not change either by acids or alkalies.

Green Indigo.

About the year 1790, Mr. Alderman Prinsep, who had then lately returned from *India*, gave me a specimen of indigo obtained *there*, as he informed me, from a tree, (which I then suspected to be the panitsjica-maram, of the hortus malabaricus, though I now suppose it must have been produced from the nerium tinctorium, lately mentioned ;) and he, at the same time, gave me a very small piece of a hard green substance, likewise produced in the East Indies, and which he called *green* indigo.

Upon seeing it, I flattered myself with a hope of its proving to be what the late Mons. de Poivre had mentioned in a little work, published under the title of "Voyages d'un Philosophe," &c. as obtained by the inhabitants of Cochin-china from a plant called *tsai*, which, when macerated and fermented like indigo, yields a *green* fecula, capable of dying a fine, as well as a lasting emerald, or green colour.* The quan-

* Loureiro mentions, (tom. i. p. 25, of the original Lisbon

tity of this green substance so put into my hands, was much too small even for a single decisive experiment. I however divided it into three parts. One of these I put into boiling water, which appeared to have no action upon it; but it was afterwards dissolved by a little oil of vitriol, like common indigo, producing, however, a green, instead of a blue colour. A second of these parts I dissolved with a little caustic alkali and orpiment, in order to see whether, excepting the difference of colour, it would possess properties similar to those of indigo, when dissolved by the same means, and like the latter be able to produce a fixed colour on linen or cotton by topical application. This, however, it did not seem to be capable of doing: the remaining part I put into a little spirit of wine, which dissolved a portion of it, though very slowly; a circumstance in which it differs materially from indigo, and seems in some degree to resemble that green-coloured fecula which some plants afford, and particularly the cruciform, when fermented like the indigo plant in warm weather. I confess, however, that these

edition,) the justicia tinctoria, as growing wild in Cochinchina, adding "folia viridi colore saturata, eodem telas pulchre imbuunt." Whether the plant, whose leaves alone are here represented as capable of producing a *green dye*, has any relation to the *tsai* of M. de Poivre, I know not.

experiments were made on such very small quantities of the substance under consideration, that very little dependence ought to be placed upon them. But this is certain, that if a simple or homogeneous *green* colouring matter exists, and can be discovered, with properties in other respects similar to those of indigo, it will be a most important addition to the Materia Tinctoria.

Barasat Verte.

In the year 1793, Messrs. John and Francis Baring, and Co. received from R. C. Birch, Esq. of Calcutta, parcels of two new drugs, intended for dying; samples of which were put into my hands, with a request that I would make suitable trials of their merits; and with a paper containing some explanations which had accompanied them from India. One of these (and the only one which I shall notice at this time) was called Barasat Verte, and was formed into dry hard cakes, resembling in size and shape those of the indigo sent from Bengal; but of a dark dull green colour. It was stated to be a simple substance, and to have been prepared with water and fire only, "from an *indigoferous* plant, an ever-green, with leaves somewhat resembling those of the laurel, bearing large clusters of small yellow flowers, and producing seed in large pods, pointed at the end,

and it was added, that the *seed did "not vegetate in Bengal.*" It was also represented as giving a durable light green colour, without any mordant or basis, to silk and wool; and to be incapable of dying dark green without the aid or addition of some blue colouring matter. To bring this green indigo into a state fit for use, it was directed to be finely levigated with sand, and then boiling hot water was to be poured upon the powder in a suitable vessel; and being left to settle, the water "tinged with a dirty brown colour was to be poured off;" and these washings were to be repeated until the water came from the powder colourless; and then to the remaining powder, an equal quantity of fixed vegetable alkali, obtained by calcining salt-petre upon burning charcoal, was directed to be added, with a proportionate quantity of water, and the mixture made to boil for two or three hours; after which, it was to be left "to digest for two days at least." In this preparation, diluted with boiling water, the silk or woollen stuff was directed to be dipped for the space of half an hour, and then washed with soap in water; a longer dipping was represented as giving no greater body or depth of colour.

After what has been just mentioned on the subject of *green* indigo, it will naturally be concluded, that my curiosity must have been greatly excited by that now under conside-

ration; and indeed I lost not a single minute in making such a trial of it, as would decisively ascertain whether it really possessed the properties of indigo, with only the difference of a green instead of a blue colour. This was by powdering and boiling it in water with a suitable portion of lime, pot-ash, and red orpiment, as is practised in making the printer's blue for penciling; (see page 113, &c.) and in doing this, I soon perceived, with great satisfaction, that the mixture exhibited exactly the same smell, and the same appearances, as those which arise in making the printer's blue; the surface of the liquor was covered with a fine shining copper-coloured scum, and beneath this, when separated, the liquor itself exhibited a lively green. Being impatient to see how far its effects were similar to those of indigo dissolved in this way, I applied some of the green liquor as expeditiously as possible, by the pencil, to a bit of calico, and soon perceived that it consisted of two very dissimilar colouring matters; one, which proved to be true indigo, was immediately revived by an absorption of oxygene, (as happens to the printer's blue when so applied,) whilst another part of the liquor spread itself farther, and retained a kind of olive green colour, which the air did not change.

The calico, after being dried, was washed with soap, and that part of the liquor which had

spread farthest, and retained the olive green colour, was soon wholly washed out, leaving behind the pure indigo, adhering to the spots and strokes where it had been applied. Having thus convinced myself that this substance contained a portion of true indigo, I powdered an ounce of it, and mixed the powder with six times its weight of sulphuric acid, as in making the sulphate of indigo for Saxon blue : in about twenty-four hours the powder appeared to be nearly all dissolved, and the solution was of a blue colour, with a greenish tinge : and by putting a little of it into warm water, and dying a small piece of flannel therein, a full Saxon blue was soon produced ; though the colour had a greenish cast, occasioned manifestly by the same olive-coloured matter which I have just mentioned as having shewed itself upon the calico.*

I afterwards tried the method recommended by the author of this discovery, of separating the yellowish brown colouring matter from the powdered green indigo, by repeated ablutions with hot water, and then employing a pure

* A small bit of the Barasat Verte being ignited, it burnt with a brisk red flame, emitting fumes, of which a considerable part exhibited the fine purple tint, peculiar to those of indigo. It left a residuum, equal to about half its bulk, of a dark chocolate colour, of which carbone seemed to constitute a considerable part, but this I did not particularly examine.

caustic vegetable alkali to dissolve the residuum. In this way I obtained a solution which, upon wool, dyed a light olive or apple green; I found, however, as I had foreseen, that none of the true indigo had been dissolved, either by these last trials, or those made in Bengal, it being impossible, as I have formerly explained, to dissolve indigo by caustic alkali alone; and indeed the discoverer of this preparation, in the account which he transmitted from Bengal, candidly acknowledges that he had never been able to dissolve the supposed green indigo "entirely, a considerable quantity having always remained precipitated at the bottom of the vessel." And this insoluble residuum, (which appears to have been lost, or at best to have remained wholly useless in all the experiments made in Bengal) I found by further trials to be true indigo. For by separating the solution made by caustic vegetable alkali from the residuum, then pouring upon the latter farther portions of caustic alkali in hot water, until the lixivium came away colourless; and afterwards submitting what remained to the action of muriatic acid, to dissolve any heterogeneous matters which the alkaline menstruum had left behind, I at length obtained a considerable quantity of indigo, of a middling quality; part of which, being dissolved by sulphuric acid, dyed wool of a good Saxon blue colour, without any of the greenish tinge which had attend-

ed my first trials; and another part being dissolved by pot-ash, lime, and red orpiment, as for the printer's topical blue, produced the usual effects of indigo in this way. Having applied the acetite of alumine topically to a piece of cotton, as is practised in calico-printing, and dyed one part of it in the yellowish brown coloured liquor, which had been obtained by pouring hot water on the supposed green indigo in powder, and another part in the olive green liquor, obtained from the same powder by caustic vegetable alkali, I found that, though each imbibed a different colour, neither was fixed upon the figures which had been printed with the aluminous basis, or on the parts to which no mordant or basis had been applied, and that the colours were removed by washing with equal facility from every part: a certain proof that the yellowish brown and olive green colouring matters were not of the adjective kind, (having no affinity with the aluminous basis,) and that they are not likely to be of any use in dying; for though they should prove lasting upon woollens, there are many other and much cheaper means already in use for giving colours of this kind to wool. It seems evident, therefore, that the true nature of the supposed green indigo was but very little known to the discoverer thereof; and that its useless heterogeneous parts were the only ones which produced

the colours dyed in Bengal, and which induced him to send it to Europe as a dying drug.

Whether the supposed green indigo owes its production to an insufficient combination of oxygene; or, in other words, whether the matters which dyed the yellowish brown, and the olive green colours, before mentioned, are similar to that which forms the basis of true indigo, and capable of being converted thereto by a longer fermentation, agitation, &c.; or whether they are of a nature essentially different from the basis of indigo, though naturally combined with it in the particular plant whence the substance under consideration is extracted, are important questions which I am unable to answer. I have indeed mixed the supposed green indigo, in powder, with water, and kept the mixture for several days at a degree of warmth suited to promote a fermentation, but without being able in this way to render its colour blue, or increase the proportion of true indigo which it had before contained: but perhaps I might have been more successful with a greater quantity, or a larger fermentible mass, than what I was able to employ in this way.

I have had reason to conclude, that the supposed green indigo, either from a redundance of colouring matter in the plant from which it was extracted, or from some other cause, may be obtained at much less expence than the true

indigo; and if this be the case, it must doubtless prove a very important discovery, if the yellowish brown and olive green matters are capable of being changed to indigo, by a farther combination of oxygene: and even if this should not be the case, perhaps the plant may deserve attention, on account of the portion of true indigo which it unquestionably affords; and which, by an alteration in the process, might doubtless be precipitated and collected, free from the other matters before mentioned, which, at best, can only be considered as a troublesome incumbrance, without any such benefit as Mr. Birch appears to have expected from them.

The preceding account of the *Barasat Verte*, was published by me in 1794, excepting the *names*, which I did not consider myself as at liberty to mention. I had not then been informed that when my attention to this subject was requested by Messrs. Baring, the nearest relation of Mr. Birch in this country, had also engaged Dr. Higgins to employ his chemical science and means upon the same matter; and, consequently, the report which I made, and which was transmitted by Messrs. Baring to Calcutta, was founded solely upon the results of my experiments. I discovered afterwards, however, by some letters from Mr. Birch, (of which extracts were communicated to me,) that

the report of Dr. Higgins in regard to the merits and value of the Barasat Verte, had been much more favourable than mine; he having, according to Mr. Birch's summary account, stated it to be "a novelty, producing fine dyes, going farther than indigo, and rivalling it, in the solidity and lustre of its colours." Fortunately for Mr. Birch, he did not, on the strength of this report, precipitately engage in an extensive manufacture of this article, as he might have done, if my opinion had been equally favourable. One of his letters contains this observation, "Dr. Bancroft's experiments, and remarks, appear to have been made with much good sense, candour, and kindness; had he given as favourable an opinion as Dr. Higgins, I should have had more dependence than I can now have, &c."

Mr. Birch did not, however, relinquish this object, until by sending to this country, several parcels of the Barasat Verte, and getting it used by dyers, he became fully satisfied, that it had no other value than that of the indigo contained in it; and that, *as indigo,* this was not the most advantageous form, or method of preparing it.

The manufacture of this dye being now abandoned, I may, without impropriety, intimate my belief, that the Barasat Verte was obtained, from the *taroom akkar* of Mr. Marsden,

(lately mentioned at p. 189,) which Dr. Roxburgh has denominated asclepias tinctoria, (belonging to the natural order of contortæ,) and which was introduced at Calcutta, a little before Mr. Birch produced the Barasat Verte. What the latter mentions of its leaves, p. 266, agrees with Mr. Marsden's account of them; and Mr. Birch's observation, that the seed did not vegetate in Bengal, is conformable to Dr. Roxburgh's remark, that it did "*not ripen its seed*" in the Botanic garden at Calcutta, nor in that of Samulcota. (See Trans. of the Society of Arts, &c. vol. 28, p. 302.) The latter also mentions *hot* water, as necessary to extract the colouring matter of the leaves of the taroom akkar, which enables us to understand why Mr. Birch has included *fire* among the means employed to prepare the Barasat Verte. Probably this "stately useful creeper," as Dr. Roxburgh terms it, contains a larger proportion of extractive matters, than other plants yielding indigo, (which the hot water would copiously extract,) and the precipitants employed by Mr. Birch, may have been such as to throw these matters down abundantly, intermixed with the indigo.

Dr. Roxburgh describes another species of swallow wort, under the name of asclepias tingens; which is, he says, "a large twining shrubby plant, brought from *Pegu* in 1795, to the Botanic garden at Calcutta, where it thrives

well." He adds, "Dr. Buchanan, who brought the plant, informed me, that from its leaves, the *Burmah* people prepare a *green* dye."—"I have made, (he adds) a variety of experiments with the view of obtaining the green dye above mentioned, but without success."—"But this information is from so respectable a source, as to induce me to hope, some better qualified person may be able to discover how this green dye is to be obtained and applied." See Trans. of the Society of Arts, &c. 28, p. 305.

Formerly the *soot* of burnt wood was employed substantively to dye woollen cloths of an olive green colour; though it seems now to be rarely used. It gave cloth an unpleasant smell, which was, however, in some degree compensated, by the certainty with which the cloth was afterwards, thereby preserved from the depredations of moths.

Turmeric.

Of substantive vegetable yellows, the only one employed in Europe, and deserving of notice, is the root of the Curcuma, or Turmeric; which, without any addition, yields a fine bright colour, though of but little durability. Of this there are two species, the Rotunda and the Longa. The latter is very generally employed in the East Indies, as a condiment with animal food. The former, or *round* root, is

chiefly cultivated for dyers' use. Loureiro, after mentioning both species as growing wild, and also by cultivation, in China and Cochin-china, adds, concerning the round, "radix ista non est esculenta: ad tingendum adhibetur colore *quidem pulchro*, sed inconstante." (Tom. i. p. 9.)

This beautiful colour has not the smallest affinity for any metallic or earthy basis. I have applied solutions of alumine, tin, iron, and all the other metals, in *spots*, to calico; and after drying and rincing, have dyed it with turmeric, which, unlike any of the adjective colouring matters, was imbibed *most* copiously, upon the parts which had received *no basis* or mordant; and the colour being exposed to the sun and air, it did not prove more fugitive upon these parts, than on those to which alumine, tin, iron, &c. had been applied. It is worthy of remark, also, that the colour itself was not altered by any basis.

In 1793, Mr. Bayley, who was extensively engaged in dying silk handkerchiefs to imitate those of India, informed me, that the yellow spots in these hankerchiefs were all produced by a tincture of Turmeric, made by digesting six pounds of the powder (of Turmeric) in a gallon of malt spirit, and afterwards, by a *press*, separating three quarts of a rich tincture, which cost about four shillings the quart, and was applied topically, and without thickening, to

parts or spots of the silk handkerchiefs, which in the dying had been *reserved white* by the usual means.

I found that a tincture of turmeric obtained in this way, and gummed, when applied topically to calico, produced a beautiful yellow, which, by washing with soap, was made *red;* but being well rinced, and exposed to atmospheric air, it again became yellow; and in this way would bear several washings.

Mr. Clarkson, in his essay on the impolicy of the African Slave Trade, relates, that "a gentleman, resident upon the coast, (of Africa,) ordered some wood to be cut down, to erect a hut: whilst the people were felling it (continues Mr. C.) he was standing by, and, during the operation, some juice flew from the bark of it, and stained one of the ruffles of his shirt. He thought that the stain would have washed out; but, on wearing it again, he found that the yellow spot was much more bright and beautiful than before, and that it gained in lustre every subsequent time of washing." Pleased with the discovery, he sent home a small sample of the bark, which "produced a valuable yellow dye, *far beyond any other ever in use in this country.*"

Mr. Clarkson adds, that this gentleman "is since unfortunately dead, and little hopes are entertained of falling in with the tree again."

The colour mentioned in this account, if there be no error in it, must have been of that kind which I have denominated substantive, as capable of being fixed by dying, &c. without the aid of any aluminous or other basis.

M. du Pratz, in his history of Louisiana, also mentions a tree, or shrub, seldom exceeding the thickness of a man's leg, the wood of which, he says, is yellow, and yields a juice of the same colour, if cut in the sap. Both the wood and the juice he says, have a disagreeable smell; and the former is used by the natives for dying, first cut into small pieces, and boiled in water, into which they dip feathers, hair, &c. He calls it ayac, or stinking wood; and as he mentions nothing of the use of alum, or any other basis or mordant, this, if his account be accurate, must also be a substantive colour. I fear, however, that the information of persons, not particularly acquainted with the subject, cannot be much relied upon respecting the natures and properties of dying drugs.

The roots and bark of the Berberis vulgaris, Lin. or Barberry shrub, are naturally of a fine yellow colour, which they communicate to wool, *without any basis;* but it has not the smallest degree of permanency against the action either of air or soap. This shrub indeed furnishes a remarkable instance, to shew how little can be discovered respecting the colouring

properties of plants from their external appearances. A similar instance lately occurred to me in the wood, bark, and root, of the Zantoxylum clava Herculis, Lin. (the tooth-ach tree, or Japan pepper tree,) every part of which is strongly coloured of a most beautiful yellow; but having procured some of it for trial, I could extract but little colour from it, notwithstanding its seeming abundance of tingent matter; and the little which I did extract, was, like that of the Berberis, utterly incapable of forming the least union with any basis, or of resisting the action of air, or of soap, in any degree.

In a note to p. 184, I have referred to a letter from Dr. Roxburgh, mentioning that he had sent from India, for trial by me, a parcel of "the coloured tubes of the blossoms of nyctanthes arbor tristis, Lin. which the Hindoos employ to give a most beautiful but fugitive orange colour to cotton; and I found that these tubes, by mere infusion, even with cold water, yielded such a colour as Dr. Roxburgh has described, and that it took readily upon cotton and silk, by mere cold maceration; but it had no affinity or attraction for alumine, the oxides of tin, iron, or any other basis, or mordant; and I therefore conclude that, in the present state of our knowledge, there is no probability of rendering it permanent; though, as a substantive colour, it resisted the sun and air, for a very few days, on

calico, and for a week on silk, and disappeared gradually, rather by losing body, than by any degradation or change of its tint: strong muriatic acid did not appear even to weaken the colour, but it was immediately discharged by undiluted nitric acid, leaving the calico perfectly white: oil of vitriol had less action on the colour; though it burned holes on the dyed cotton, it was not changed by washing with soap.

Annotta.

The seeds of the Bixa Orellana, Lin. (growing spontaneously in different parts of Guiana,) are covered with a reddish pulp, which is collected and sent to Europe in different forms, under the names of annotta, arnotta, and roucou. It is principally employed for dying silk, and sometimes for cotton; though its colour, by all the ways and means of applying it, hitherto discovered, is so fugitive, that perhaps it would be better if it were never employed, even for dying silk. It partakes so much of a resinous nature, as to dissolve but very imperfectly in water; and therefore at *least* an unequal weight of potash is employed to render it soluble in that vehicle, and afterwards the silk or cotton is dyed therein without any aluminous or other basis.*

* The liquid sold in different parts of the town, under the name of "Scott's Nankeen Dye," appears to be nothing but an alkaline solution of this drug.

The colour of annotta becomes less red, and more inclined to the orange, when separated from the seeds by maceration, in water, as is usually practised; and by the addition of pot-ash, it is made to incline still more to the yellow hue. This last change may, however, be readily overcome by adding any of the different acids to the dying liquor, after sufficient colour has been taken up, by the silk or cotton dyed therein; and afterwards prolonging the dying for a quarter of an hour: argol or tartar is generally preferred for this purpose, because it not only raises the colour, but seems to render it a little more fixed; so much of it should be used, as to make the liquor moderately sour. It is remarkable, that though the colour dyed with annotta fades very fast by exposure to air, it resists soap, and the action of acids, better than some colours which are much more permanent. And it certainly affords one, among several instances, of colours which decay by causes very different from combustion; because linens and cottons, dyed in the usual ways with annotta, suffer less than madder colours from the oxymuriatic acid. The fresh pulp of the Bixa Orellana, taken immediately from the shrub whilst growing, and applied to cotton without the addition of any alkali, seemed to afford a colour more lasting, and approaching nearer to the red, than that dyed from the pulp, separated by

maceration, as in the common annotta.* The greatest consumption at present of this article, at least in Great Britain, is, in giving to cheese a kind of yellowish orange tint, for which it is very suitable, as being harmless, and nearly tasteless.

The Lawsonia inermis of Linn. has long been used throughout India, Persia, Arabia, Egypt, and in many other parts of Africa, for giving a reddish stain to the nails, lips, &c. It is the Ligustrum Ægyptiacum of Prosper Alpinus, and the Hinna of the Arabians. Sir William Jones relates, that being at the island of Hinzuan or Johanna, and observing a very elegant shrub, about six feet high, not then in blossom, he learned, that it was the "Hinna," of which he had read so much in Arabian poems. "Musa (one of the inhabitants, says he) bruised some of the leaves, and having moistened them with water, applied them to our nails, and the tips of our fingers, which in a short time became of a dark orange scarlet."—Nieuhoff says, they prepare the tincture by steeping the

* M. Leblond has proposed (Ann. de Chim. tom. 47) to separate the colouring matter from the seeds of the Bixa Orellana, simply by washing them with water, and after precipitating the coloured matter by lemon juice of vinegar, to render it dry and hard by evaporation; and Vauquelin having made experiments with the colour so prepared, concludes it to be worth, at least, four times as much as the common annotta.

leaves after they have been rubbed small upon a marble stone, in fair water, mixed with a small quantity of lime."—"With this (continues he) the Turks and Persians also, dye their horses tails." This shrub according to Adanson, is called foudenn, by the negroes of Senegal, where it is used, both by the men and women, to give their nails a red stain, which lasts until the substance of the nails changes by growth. As the colour of this shrub requires no kind of basis or mordant, it must naturally belong to the class of substantive colours.*

* This account of the Lawsonia inermis, was published in 1794, before I had seen any of it. But in 1801, my son, being in Egypt, as physician to the British army there, sent me several packages of the leaves, dried and powdered; and by the experiments which I have since made with this powder, I am inclined to think, that it ought to be removed from its present arrangment, and placed among the adjective colours. For though great quantities of it are employed substantively as a dye, it has a decided affinity for the basis of alumine, and that of iron, giving with the former a permanent orange-brown to calico, and with the latter a brownish black.

Sonini represents the dried leaves of this plant, as a valuable orange or reddish dye, and says, that 14 or 15 ships were annually loaded with them at Alexandria, and sent to Constantinople, Smyrna, and Salonica, whence a part was exported, particularly to Germany, and there used "in dying furs, and the preparation of leather."

Another species, which is *thorny*, possesses the same tingent property. Hasselquist says, the practice of dying the nails with the Lawsonia spinosa (alhenna,) is so ancient in Egypt, that he has

I lately received a few ounces of small seeds, inclosed in a flea-coloured husk, but without any information respecting the plant on which they grew. They were brought from the coast of Barbary, where, as I was informed, they are used in dying red or pink colours. In two or three small trials which I made with them on silk, they appeared to possess a substantive colouring matter, similar in some respects to that of safflower. At first I thought they might be the seeds of the gardenia florida, which, according to the accounts of Mr. James Cunningham, who formerly travelled into different parts of the East Indies in pursuit of natural curiosities, the Chinese employ for dying *scarlet*, under the name of *unki.** I found, however, that this could not be the case, as the seeds of the gardenia grow inclosed, several of them in one common capsule, involved in a rich-coloured mucilaginous sub-

seen the nails of *mummies* dyed therewith. He adds, that the powdered leaves are annually exported in great quantities.

Lourerio says, of the Lawsonia spinosa, " foliis contritis admixta calce, utuntur Cochinchinenses, ad tingendos ungues colore ruberrimo: qui mos pro elegantia invaluit non solum apud alios populos Indianos, sed etiam apud Turcas, Persas, Æthyopes." Tom. i. p. 229.

* Dr. Plunkenet, in his Amaltheum, page 29, says, " Semina tinctoribus inserviunt üs enim ab indigenis Sinensibus optime tingitur nobilis ille color, quem *escarlatinum* nostrates vocant, ut nos monuit vir multiplicis industriæ atque indefessi laboris hac in parte, D. Jacobus Cunninghamus."

stance; whereas the Barbary seeds evidently grew without any such inclosure. I cannot discover whether the seeds of this gardenia, or the mucilage surrounding them, ought to be considered as a substantive or an adjective colouring substance; all accounts being defective in this respect.*

Safflower.

This is the Carthamus tinctorius, Linn. which is cultivated in the southern parts of Europe, Egypt, &c. and also in the East Indies, whence

* When the late Sir George Stanton returned from the embassy to China, in which he was associated with Lord Macartney, he gave me some yards of a cotton cloth, which had been dyed scarlet, and probably from the gardenia florida, (now called cape jasmine in this country.) It was one of the articles mentioned by Mr. Barrow in the following words, viz, "among some of our presents were also *pieces* of a *beautiful scarlet*." (P. 560.) The colour of the cloth so given to me, certainly approached nearer to the cochineal scarlet, than any which I have seen dyed on cotton, in Europe, and it seemed to be of a resinous nature, dyed substantively without any basis, and capable of bearing exposure for a reasonable time to the sun and air, but liable to be in a considerable degree discharged by washing with soap. Concentrated oil of vitriol had but little effect upon this scarlet.—Strong muriatic acid changed it to an orange; and double aquafortis made it yellow. So that it was much less injured by these acids, than colours vastly more durable are known to be.

Loureiro moreover mentions another species of this genus, viz. gardenia grandiflora, whose succulent berries, recently gathered, are, as he says, (tom. i. p. 147.) employed to dye silk of an elegant red colour.

considerable quantities of it have been lately imported to Great Britain. There are two varieties of this plant, one of which is distinguished by having much broader leaves than the other. Berthollet mentions the narrow-leaved as that which is cultivated in Egypt, whence considerable quantities of it are from time to time exported.* It is the *flower* only of this plant which is employed in dying, and which affords two sorts of colouring matter, one soluble in water, and producing a yellow of but little beauty, when dyed adjectively, on an aluminous basis; the other is *resinous*, and best dissolved by the fixed alkalies: it is this last which alone renders safflower valuable in dying, as it affords a red colour, exceeding in delicacy and beauty, as it does in costliness, any which can be obtained, even from cochineal, though much inferior to the latter in durability.

To obtain this red colour of safflower, it should be tied up in a linen bag, and subjected to maceration and pressing in clean running water, until all the yellow colouring matter is dissolved, and washed away, and the flowers which were previously yellow, are made red by an abstraction of this yellow colour. This being done, the flowers are again to be macerated in a solution of clean

* Niebuhr says, there are 10 varieties of safflower cultivated in Egypt, and that the quantity annually produced, commonly amounted to between fifteen and eighteen thousand quintals.

soda, in quantity sufficient, and only sufficient, completely to dissolve and extract the resinous or beautiful red colouring matter; which is to be separated by draining, and the application of more water to the residuum, until the whole is abstracted and collected for use. To fit this colouring matter for dying, the soda by which it was extracted, is to be neutralized by an acid; and for this purpose the *citric* acid is generally preferred to all others; and more especially that which is contained in lemons, or limes beginning to rot or spoil; or in their juice, when it has been kept some months in casks, and the mucilage has suffered a partial decomposition. Next to the citric acid, that of tamarinds, and of tartar, are thought most suitable; though Bergman has recommended the sulphuric, as next to the citric, if it be not used in excess. But Scheffer pretends that the acid juice of the berries of the pyrus acuparia, or mountain ash, produces a better, and more lasting colour than even the citric acid.

The colour of safflower will not bear the action of soap, nor even that of the sun and air, for a long time; and being more costly than even the colour of cochineal, it is principally employed for *imitating upon silk* the fine scarlet (ponceau of the French) and rose colours, which are dyed with cochineal upon woollen cloth. Beckman pretends that by preparing cotton as for the Turkey red, and dying it with safflower, the co-

lour was rendered much more durable, than it is by the ordinary process; but in this way it will cost so much, and after all prove so inferior, in point of *durability*, to the Turkey red, that this method of employing safflower, does not seem likely to be ever adopted.

The fine *rose* colour of safflower, extracted by crystallized soda, and precipitated by citric acid, and then slowly dried in the shade, being afterwards finely ground with the purest talc, produces the beautiful paint by which ladies give to their cheeks the bloom of youth and health, and which the French distinguish from carmine by the name of "*rouge vegetale*."

Aloes.

M. Fabroni, in a memoir printed in the 25th volume of the Annales de Chimie, has stated, that the almost colourless juice of the aloë succotrina angustifolia, by exposure to atmospheric air, assumed a fine purple colour from an absorption of oxygene, and that he had dyed a beautiful and lasting purple with it upon *silk*, without any mordant or basis whatever, and in the 68th volume (p. 165) of the same work, M. M. Bouillon Lagrange, and Vogel, have asserted, that nitric acid, heated with powdered aloes, produced a beautiful yellow powder, which, on being mixed with water, gave to the latter, a magnificently rich purple colour: that a single atom was suffi-

cient to colour a large portion of water, and that the colour was so permanent, that when applied to the fingers, the stain continued several days, especially if a little alkali had been previously mixed with the powder.

Encouraged by these statements I was induced, when this volume was nearly ready for a second impression, to rub, in a glass mortar, some of the best Barbadoes aloes, and pour upon it a little strong nitric acid, to which, after it had been mixed with the aloes, I added three or four times as much water; and with this mixture farther diluted, I the next day dyed some pieces of white broad cloth and calico; the latter took only a sort of tobacco colour; but the cloth soon exhibited a rich, though *brownish*, purple, of considerable brightness, and which, after exposure to the sun and air during all the month of July (1812,) had suffered no change, excepting that it seemed, perhaps, half a shade darker and fuller than at first. I conclude therefore that this colour is eminently durable. It had, however, too much of the chocolate brown in its composition to be deemed a beautiful purple. I tried a similar mixture, with a nitro muriate of tin, and with alum, but neither of them appeared to improve the colour in any way. I also tried it with sulphate of iron, which produced no change.

How far it might be practicable to render this aloetic colour strictly a fine purple, and how

far, in point of cheapness, it would be advantageous for common use, are questions which I am not yet able to answer. Perhaps the more common Barbadoes aloes, might answer as well as that with which my experiments were made. I mean soon to ascertain this fact.

Aloes powdered, and mixed with strong sulphuric acid, produced only a snuff colour upon broad cloth, and with muriatic acid, it produced only a lighter brown; the purplish colour before mentioned, is therefore an effect of the nitric acid alone.

Orchall and Cudbear.

The Linnean genus of Lichen, belonging to the natural order of algæ, contains numerous species, of which several, after being macerated with ammonia or volatile alkali, afford beautiful violet, purple, and crimson, substantive dyes; of these the most valuable is obtained from the lichen roccella, Linn. which in the quantity, vivacity, and durability of its colour, excels every other species of lichen; though unfortunately even this cannot be deemed a fast or permanent dye. Dr. Dillenius has given an accurate figure and description of it in his excellent and elaborate "Historia Muscorum," Oxonii 1741. 4to. p. 120, tab. 17, fig. 39, under the name of coralloides corniculatum fasciculare tinctorium, fusci teretis facie." And he thinks, with reason, that it is the identical

τοτοντιον φυκος, or alga marina of Theophrastus, and the Λειχην of Dioscorides, mentioned by them as being in great use and estimation for dying wool, of a colour more beautiful, when first dyed, even than the Tyrian purple.* Pliny also mentions it, as I have already noticed at p. 126, and in his 26th book, chapter 10, he calls it "Phycos thalassion;" "id est fucus marinus;" adding, that it serves as a *ground* for the shell purple, "qui conchyliis substernitur:" and in his 32d book, chapter 6th, he mentions it again as one of the "algæ maris," of which, says he, there are several kinds, and among them that of *Crete* is most commended, &c. "Laudatissima quæ in creta insula juxta terram in petris nascitur; tingendis etiam lanis *ita colorem alligans,* ut elui postea non potest." He was however greatly mistaken in thus supposing that it contributed to render other dyes more fixed or lasting.

After all knowledge of the use of this lichen had (in common with arts and sciences) been lost for several centuries in the west of Europe, it was restored at Florence early in the 14th century, by a Florentine, descended from a German named Ferro, or Frederigo, who having resided some years in the Levant, and acquired information respecting the properties of this

* Theophrast. Hist. Plant. iv. c. 7. p. 82. Ed. Heinsii. Dioscorid. Lib. iv. c. 95.

lichen, returned to Florence, and there introduced, and exclusively enjoyed, the use of it in dying, for some years; and acquiring great wealth, became the founder of one of the principal Florentine families, who took the name of Oricellarii (afterwards abbreviated to Rucellarii and Rucellai,) from the name of *Oricello*, by which this commodity was afterwards distinguished in Italy: and the Italians having thus become acquainted with the preparation and uses of this lichen, engrossed for a century, all that could be procured of it among the islands of the Archipelago, and on the shores of the Mediterranean, until the discovery of the Canary islands (which had likewise been lost) in 1402, by John de Bethencourt, a Norman, relieved the other nations of Europe from their dependance upon Italy for this commodity.*

* I have now before me the scarce "Histoire dela premiere decouverte et conquete des Canaries, &c." by this Bethencourt, (described as chamberlain to the French king Charles VI.) stated to have been written by two priests (Boutier, and Le Verrier) who were in his suite, and published by "Galien de Bethencourt, Conscillier du Roi," in the parliament of Rouen, (printed at Paris in 1630,) in several parts of which, mention is made of this commodity, particularly at p. 130, where, in describing the productions of these islands, I find these words "Et y croit une graine qui vaut beaucoup, qui on appelle *orsolle*; elle sert a teindre drap ou autre choses, et est la meilleure graine que l'on sache trouver en nul pais pour la condition d'icelle; et si cette isle est une fois conquise et mise a la foi chretienne, icelle graine sera de grand valeur au sieur du païs;" and in a note

At a much later period (i. e. about 1730) the orchella was discovered growing abundantly and luxuriantly at the Cape de Verd islands; where it had been left to acquire full maturity, unmolested, and was found to be much larger and richer in colouring matter, than any which had been previously known. The quantity had however been considerably diminished, when Wadstrom was there about half a century afterwards. The labour of gathering the orchella then cost, as he informs us, about five shillings sterling the quintal, and the medium price at Porto Praya, was about 3000 reas, (or 18*s.* 6*d.* sterling;) but when carried to Lisbon, it sold for 19,200 reas, more than six times as much. It often sells at London for 300*l.* sterling per ton, and sometimes for more than 1000*l.*

Ray, (His. Plant. i. p. 74,) has given, from Imperatus, a short account of the preparation of Orchella for dying; and Micheli has since published one, which is more circumstantial, and probably conformable to the practice of

the following explanation is subjoined, "Orsolle graine a teindre de grand prix, oriocola ou oricola, dont se fait grande trafic par tout." Afterwards, at p. 180, I find, that Bethencourt, among other regulations, prohibited all persons from dealing in this commodity, meaning to reserve the profits of it exclusively to himself, as the kings of Spain have since done in the islands of Canary, Teneriffe, and Palma. The Canaries have since annually produced about 2,600 quintals of Orchella.

the Florentines. The means employed were human urine, and either pot-ash or soda, with which the powdered lichen was mixed, macerated and fermented (in close wooden vessels) for several weeks, until the resinous colouring matter, by combination with the ammonia of the urine, had been sufficiently evolved and dissolved: after which, it was preserved in a moist state in tight casks, sprinkling the surface when necessary, with urine or lime water, until wanted by the dyer. Lime has since been substituted for pot-ash and soda, as several other species of lichen have been for the rocella, or orchella, though none is of equal value or utility. One of the best of these substitutes probably is a lichen, which Imperatus has described and figured, (Hist. Nat. xxvii. cap. 11,) as growing on rocks near the sea in *Candia*, and there called *rubicula*; it is nearly related to the orchella, and frequently mixed with it. Linneus has named it lichen fuciformis. It grows also in the East Indies.

The French have for several centuries employed in this way, a species of lichen called by them *perelle* from a corruption of the word *pierre*, (stone) it being commonly found adhering to volcanic stones, or productions; and it has been generally supposed and stated to be the lichen parellus of Linn. but it appears certain, from a "Memoir" by M. Cocq, just published in the 81st

volume of the Annales de Chimie, that this is a mistake; that in Auvergne where this lichen is principally gathered, the true lichen parellus of Linneus is called la pommelée, and that this is constantly rejected by the persons employed to gather the *perelle*, as being unfit for their purpose: and indeed M. Cocq found, by suitable trials, that the lichen parellus of Linn. would only yield "un chamois rougeâtre." And he asserts most positively, that the moss collected and employed to produce l'orseille d'Auvergne, (sometimes also called orseille de terre) is the variolaria orcina of Acharius,* (which Dr. Westring has mentioned as affording a beautiful colour;) that this is generally, and invariably denominated *perelle* in Auvergne, and that, when prepared in the usual way, it afforded "la belle et vive couleur rouge *amarante*, qui les teinturiers du pays en tirent." It sells he says in Auvergne, for between 12 and 24 sols the pound, and a labourer may gather four pounds daily. M. Chaptal says, the English used to obtain it on the coast of Italy; (probably at the isle of Elba.)

M. Cocq gives, in the same memoire, a particular account of the process by which the *perelle* is prepared for dyers' use, at *Clermont;* he having been extensively engaged in that business for several years. It appears that wooden troughs

* Meth. Lich. suppl. p. 6.

are employed as usual to macerate and ferment the *perelle*: that these troughs are commonly about six feet in length, two or three in breadth (but narrowest at bottom,) and about two feet in depth; and that to each trough a cover is exactly fitted, so that it may retain as much as possible of the volatile alkali of the (human) urine; of which 240lbs. are commonly employed for every 200lbs. of the perelle; this last being the quantity usually allotted for each trough, and which it will about half fill. In such a trough the perelle and urine are to be well mixed, and afterwards stirred every three hours, during two days and nights, taking off the cover *only as often*, and as *long* as is necessary for the stirring. On the third day, 10lbs. of sifted and slacked lime are to be added, and well mixed, together with a quarter of a pound of arsenic, and as much alum. The workmen are to avoid the fumes of the arsenic as much as possible, for some hours after its admixture.—But when there is no longer any danger from these fumes, the stirring is to be repeated several times, once each quarter of an hour, and afterwards at the intervals of half an hour, until the fermentation is established; after which the mixture need only to be stirred often enough to hinder the formation of a crust on the surface, which, by obstructing the fermenting process, would hinder a complete formation and evolution of the colour. When the fermentation has sub-

sisted 48 hours, it commonly begins to slacken, and is then to be excited by an addition of 2lbs. more of sifted lime, and the stirring repeated once every hour until the fifth day, when the frequency of stirring may afterwards be gradually diminished. On the eighth day, there will be a considerable, but not a complete manifestation of the colour; and, therefore, the operation is to be continued a fortnight longer; (stirring the mixture at intervals of six hours,) and even after this, it is commonly thought safest and best to extend the process another week, making in all a lunar month; though when the perelle is rather deficient in colouring matter, three weeks will fully suffice.

The colouring matter so produced, is afterwards to be kept *moist* in closed casks, in which it will improve during the first year; remain stationary during the second, and begin to decline in quality afterwards. When the volatile alkali has evaporated, the *orseille* (as it is called when so prepared) acquires an agreeable violet smell, and by simple boiling it will, says M. Cocq, dye upon cloth "*un amarante*;" and with longer boiling "*un amarante foncé*." I shall presently offer some observations upon this process, when treating of the preparation of *Cudbear* in this country.

During many years, perhaps several centuries, the inhabitants of Sweden, Scotland, Ireland, Wales, and some of the northern parts of Eng-

land, have employed different species of lichen, macerated with urine, in their domestic dying.—One of these, the lichen omphalodes, Linn. has been commonly called cork, corker, and arcel; and in Wales kenkering; and it gave a kind of dark crimson to wool and woollen stuffs. It is the lichenoides saxatile tinctorum foliis purpureis of Ray. (Synops. p. 74, No. 70.) Linnæus says, (in his Flora Lapponica) that an immense quantity of this lichen grows on the Island of Aland, in the Baltic.

The lichen calcareus, Linn., or lichenoides tartareum tinctorium candidum tuberculis atris of Dillenius, (p. 128) which grows exclusively on limestone rocks, possesses similar properties, and has been long used in the same way, by the people of Wales, the Orkneys, &c.

Nearly similar colours may be obtained from several other species of this genus, (by maceration with lime and urine) particularly the lichen saxatilis, Lin. (or lichen de roche of La Marck, Flor. Franc. p. 78); the lichen caperatus, Lin. lichen pustulatus, Lin. lichen argentatus, Lin. (called cadlog, and kengevin in Wales); Lichen stygius imbricatus, &c. Lin. lichen nivalis, Lin. lichen deustus, Lin. Lichen fistulosus of Hudson, and lichen muscorum of Hoffman; which, Kalm says, the Pennsylvanians macerate three months in urine, and then dye with it a beautiful red colour.

But the most important of all the lichens produced in the northern parts of Europe, seems to be the lichen tartareus, Lin. a crustaceous moss, growing commonly on lime-stone rocks, in Sweden, Scotland, the north of England, &c. It is the lichenoides tartareum farinaceum scutellarum umbone fusco of Professor Dillenius (p. 132). Linnæus mentions, (Iter West-Goth. p. 170) that the people of West-Gothland prepare a beautiful crimson dye from this lichen, which, under the name of byttelet, is used all over Sweden; and, besides this use Dr. Westring computes, that about one hundred and thirty tons of it have been *annually* exported from that kingdom, since the year 1770. This is the lichen, with which a purple or violet-coloured powder is prepared in Great Britain, and sold under the name of *cudbear;* a name given to it by the late Dr. Cuthbert Gordon, who, having obtained a patent for this preparation, chose, in this way, to connect it with his own first name, which had been the maiden-name of his mother.

Having never seen Dr. Gordon's specification of his invention, I do not know the *peculiar novelty* by which it was distinguished—perhaps it may have been that of giving the preparation a *dry* instead of a wet form; or the circumstance of employing ammonia, obtained by *distillation* from urine, instead of the urine *itself*,

to extract and raise the colour of the lichen; a change which, whether made by him or not, certainly was a considerable improvement, as urine contains many other matters, which, at best, are but an useless incumbrance to the volatile alkali.

At the proper times and places, one person may collect twenty or thirty pounds weight of this lichen daily; but it should be allowed five years growth before it is gathered. It commonly sells at the port of London for twenty pounds the ton; but, to prepare it for use, it must be washed and dried; and by these operations the weight is commonly diminished one half, and the price, in effect, doubled. It is macerated and stirred in wooden troughs or vessels with covers, as is practised with the perelle at Clermont, in Auvergne, only substituting an *aqua ammonia*, obtained by distilling human urine, that of gramenivorous animals being deficient in the volatile alkali; the purity of which, seems to be of more importance to the beauty of the colour, than is commonly supposed.* I have prepared this colour several

* Of this fact a decisive proof lately occurred to me, in consequence of an application from certain manufacturers of cudbear, in the neighbourhood of London, who complained, that they were unable to obtain more than half the usual price of that article for the produce of their own manufactory: and, being unable to discover the cause of its manifest inferiority, they requested my assistance to remove its defects. For this

times, and am convinced, that the alum, mentioned by M. Cocq, is completely useless—and that the arsenic is both useless and dangerous; indeed, I believe the latter is not employed in this country. It seems to me, also, that much labour in stirring, and much waste of volatile alkali might be saved, by employing hogsheads instead of fixed troughs or wooden vessels. The lichen ground in a mill, properly constructed, might be put with the aqua ammonia into the bung-hole, purposely made a little larger than

purpose, they supplied me with parcels of the lichen which they had commonly employed, both in its washed and unwashed state; and also with some of their aqua ammonia, and I soon satisfied myself that the latter had alone occasioned the defects of which they complained. In making use of it, I found, that after the predominant odour of the ammonia was a little dissipated, another became, and remained prevalent, which was extremely offensive, and seemed to be the very essence of the volatile parts of solid human feces: and I learned upon enquiry, that no pains had ever been taken to separate this ordure from the urine, with which it was frequently intermixed in their collections. To ascertain the difference occasioned by this offensive addition, I macerated a parcel of the lichen with it, in the usual way, and another parcel in pure aqua ammonia, which I procured from a druggist, and with the latter, I produced very excellent cudbear, which, both in its appearance and in its effects, when applied to cloth, was equal to the finest sample which I could procure, while that produced with the impure volatile alkali, before mentioned, was *manifestly very defective*, in the look, as well as in the colour dyed from it.

common, and the bung being applied and secured, so as to hinder any leakage, the hogsheads might be rolled from time to time, so as completely to obviate all need of stirring, and all opportunity for the escape of volatile alkali, which is unavoidably very great, every time the troughs, &c. are uncovered for that operation.

The colours obtained in this way, from the several species of lichen, though possessing great beauty and lustre at first, are so fugacious, even when dyed upon wool, that they ought never to be employed, but *in aid* of some other more permanent dye, to which they may give body and vivacity; though some dyers have been tempted, by a love of gain, to employ the cudbear alone; and in one instance, a great corporation lately obtained from a London dyer, the restitution of several thousand pounds, as a compensation for excessive prices paid to this dyer for colours which ought, and were believed, to have been dyed from indigo and cochineal, though they had, in fact, been dyed from cudbear only.

I have already mentioned, that the colour obtained from the orchella is less fugacious and more beautiful than that yielded by any other species of lichen, and it is, therefore, much more costly. The application of these colours by dying is so simple and easy, that no instruc-

tion can be wanted from me on that subject. Its purple or violet tint is the immediate result of the union between the resinous colouring matter of the plant, and of the ammonia with which it is prepared; and it may be made crimson, by an admixture of, I believe, any of the acids. Alum does not in any degree render the colour more permanent; but the nitro muriate of tin is believed to produce a better effect in this respect, though it makes the colour dyed with it, approach nearer to the crimson; but I have never found that it was attended with any additional vivacity.

Cudbear in this country is chiefly employed to give body and brightness to the blues dyed with indigo, and produce a saving of that article; it is also used as *a ground* for madder reds, which commonly incline too much to the yellow, and are made *rosy* by this addition. It stains marble durably, as was first observed by Dufay.

But though, as I have lately mentioned, the purple, or violet colour obtained from these lichens, depends upon a combination of ammonia, the presence of a certain portion of oxygene also is necessary to its existence, as I have already noticed at p. 63, in regard to the colour of the spirituous thermometers. Water, coloured by prepared orchella or cudbear, and secluded from atmospheric air, loses its purple

in much less time than the spirituous tincture; and I found, that a phial being filled with it, and with a small proportion of muriate of tin, recently prepared, and closely stopped, the purple colour of the cudbear completely disappeared in less than two minutes, as I presume, by an abstraction of its oxygene. This is analogous to the extinction of the colour of sulphate of indigo by the same muriate.

Besides the lichens, whose colour depends upon a combination with the ammonia, there are some which afford substantive colours, less beautiful, indeed, but more durable, by mere boiling with water—one of these is the muscus pulmonarius of Caspâr Bauhine, or the lichenoides pulmonium reticulatum vulgare marginibus peltiferis of Dillenius, (p. 212) called Rags, and Stone Rag, in the northern parts of England; which, without any mordant, dyes a very durable dark-brown colour upon white wool or cloth; and a *fine lasting black* upon wool or cloth which has previously received a *dark blue* from indigo.

Besides the lichens affording substantive colours, there are many which, being employed *adjectivèly* with alum, or the oxides of tin and iron, are capable of dying yellows, olives, and a variety of browns—but they do not belong to this division of my subject—and as similar colours may be given at less expence, with other

means, I probably shall not notice them hereafter; but think it sufficient to refer those who may wish for more information concerning them, to Hoffman's "Commentatio de vario Lichenum usu," printed at *Lyons*, 1787.

There is a species of colouring matter diffused, in greater or lesser proportions, through the barks and other parts of almost all trees and shrubs, and which, without any basis or mordant, permanently dyes or stains wool, silk, cotton, and linen, of that particular kind of colour, which the French call "fauve," (fawn-colour) and sometimes couleur de racine, ou de noisette, (root, or hazel-nut colour). This being naturally blended with some of the more valuable colours of vegetables, frequently does harm, by degrading or obscuring them. It is found most abundantly in the peelings, rinds, or husks of walnuts, (Juglans regia) in the roots of walnut-trees, in alder bark, &c.; and it seems to acquire both body and permanency, by attracting and combining with pure air. M. Bertholet has, however, treated so fully and so well of the properties of this kind of colouring matter, when applied substantively, that I cannot do better than refer my readers to that part of his work which relates to it; observing, at the same time, that the colouring matter in question, though capable of being permanently fixed without any metallic

or earthy basis, does, in some instances, acquire new and more useful properties, when applied with a basis adjectively; which I shall notice hereafter, under the proper heads, and particularly when I come to treat of the black dye.

There are three species of poisonous shrubs, or vines, growing in North America, and containing in their stems, leaves, &c. a white milky juice, which, when applied to linen, cotton, or silk, produces a stain, which soon becomes of a full, strong, and durable *black colour*, incapable of being discharged by repeated washings, or impaired by the weather. These are the Rhus vernix, (growing likewise in Japan, and yielding the fine Japan black varnish); the Rhus radicans; and the Rhus toxicodendron, Linn. Some trials, which I formerly made in America, seemed to indicate the last of these as affording the deepest and most permanent black. But in all of them this colour probably depends on the addition of oxygene to the colourable matter; an addition which, in the formation of indigo, produces only a blue, whilst in the present instance it changes a white milky juice to the greatest possible extreme, by rendering it of a full strong black. I have found that by washing the stains before the black was completely produced, it never attained more than a blackish brown.

Marking Nut. Or Semecarpus Anacardium.

The tree which Linnæus erroneously denominated Avicennia Tomentosa, and which his son afterwards, with more propriety, called Semecarpus Anacardium, produces a nut, which has been long known under the name of Malacca bean, or *marking* nut, from the use generally made of it throughout India, to mark calico and silk. The shell of this nut is composed of double laminæ, between which are many cells filled with a corrosive resinous juice, of a pale *milky* colour, until the nut has ripened, and then it becomes a brownish *black.* It is only soluble, as far as my knowledge extends, by the *combined* operation of alcohol and *caustic* alkali, neither of which, *alone,* will dissolve it; and being dissolved, it may be made to serve as an ink, probably of great durability, and indestructible by any thing which will not also destroy paper. Osbeck says, that when the juice is employed for marking, the letters are commonly covered, *while wet,* with quick lime, to obviate the injury that might otherwise result from the corrosive property of the juice; and it seems that quick lime is very generally employed for this purpose, in the way mentioned by Osbeck, or mixed with the juice before its application. By long keeping, this juice becomes as thick as tar, and in some of the nuts which were given to me, by a gentleman

in whose possession they had been for more than ten years, it manifested no acrimony to the taste. Some of it being topically applied to white calico, without any addition, it penetrated thoroughly, and, being dried, it was afterwards boiled with soap, and exposed to the sun and weather, during two months, in which space the black colour had become deeper and more decided, as I presume, by an absorption of oxygene; but as, from the viscidity of the juice, a redundance of colouring matter had been applied, the marks seemed rather to have been *painted* than stained or dyed.

Dr. Roxburgh says, these nuts are employed by the Telinga physicians, to cure the venereal disease. They are also pickled like olives, whilst very young, and, when nearly ripe, are applied as a mild caustic to sores, &c. Lamarck, and the French botanists, have restored to this tree, the name of *anacardium*, by which it was first distinguished, from the resemblance of its nut, to the shape of a *heart* (somewhat flattened); and taking away this name from the *Cashew* tree, to which it ought never to have been applied, (as its nuts are *kidney* shaped,) they have denominated the latter cassuvium pomiferum, which is the name formerly given to it by Rhumphius.

Being at Barbadoes in the year 1805, a parcel of these nuts was given to me by Mr. Simmonds, a very promising young botanist, (then in

the family of the governor Lord Seaforth,) who was prematurely stopped in his pursuit of knowledge, soon after, by death, at Surinam. These nuts had been recently gathered, having grown on a tree in the garden of the government house, *(pilgrims,)* but were necessarily abortive, there being no male tree on the island. Their juice I found sufficiently fluid, though only of a dark-brown colour, when spread either on calico or paper, but it afterwards became *black*, by exposure to atmospheric air. Strong nitric acid changed it to an orange; but oil of vitriol did not alter, though it weakened the colour, and this was the case when muriatic acid was applied to it. Muriate of tin produced no sensible effect upon it. This juice was a little acrid to the taste.

There are a considerable number of other vegetables, whose juices by simple topical application permanently stain linen or cotton, and the stains, by exposure to the atmosphere, generally become black, or nearly so. One of these is the amyris toxifera, or poison ash, which Catesby (vol. 2, p. 40,) has described as a "toxicodendron foliis alatis fructu purpureo," &c. adding, that "from the trunk of this tree distils a liquid black as ink, which the inhabitants say is poison." "It grows usually on rocks in Providence, Ilathera, and other Bahama islands. It is also found in South Carolina and Georgia.

The camocladia integrifolia, called Burnwood, or Papau wood, and by some Maiden plumb, in Jamaica, abounds in a moderately glutinous sap, which, as Jacquin asserts, will grow black by exposure to atmospheric air, and stain the hands of a deep black colour, only to be removed, with great difficulty, by washing with soap.

Another species of this genus, the camocladia dentata, growing in South America and in Cuba, emits, when wounded, a viscid milky juice, smelling like human excrement, which, by exposure to the air, becomes black, and gives durable stains to linen, &c. as well as to the fingers. It is mentioned by Ulloa under the name of *guao.*

Another species of this genus, Camocladia punctuata, or dotted stalked Eclipta, grows in the West Indies, and contains a thin greenish sap, which turns black by exposure to the air, and may be used as ink. Jacquin says, the negroes sometimes endeavour to increase the blackness of their skins by washing with this juice.

The Eclipta erecta (cotula alba Lin.) affords a juice which the inhabitants of Cochin China, as Loureiro asserts, (p. 505.) employ to dye human and other hairs permanently black, and, therefore, call it ink plant; "herba atramenti."

Several species of the genus Rauwolfia abound in a glutinous milky juice, which blackens by exposure to the air, and gives lasting dark-coloured stains; one of these, R.

canescens, ("le bois laiteux fébrifuge," of Pouppée des Portes,) bears juicy black berries, which, at maturity, may be used as ink, without any preparation, and are said to give a lasting black stain to linen.

The hippomane mancinella, or manchineel tree, contains a very acrid juice or sap, which, if in cutting the tree, or otherwise, it falls on linen, soon produces a black stain, which afterwards becomes a hole, from the caustic quality of the sap: probably lime would correct this, as it does that of the juice of the marking nuts.

The terminalia vernix of Lamarck, (Tsi-Chu of the Chinese,) contains, in every part of it, a caustic milky juice, which, exuding from the tree when wounded, thickens and becomes black like pitch, by being in contact with the air, and is used by the Chinese as a varnish for furniture.

I could mention several other vegetables with similar properties, but believe it to be unnecessary.

CHAPTER VI.

Of Mineral Substantive Colours.

"Rien n'est plus facile dans les sciences fondées sur l'expérience que de "multiplier les faits particuliers; mais ces faits ne sont dignes d'atten- "tion, que lorsqu'ils servent à conduire à des vérités générales, ou que "présentant, au contraire, des singularités nouvelles & imprévues, ils de- "viennent un objet de recherches." HIST. de l'ACAD. Re, &c. 1777.

EACH of the metals and semi-metals is capable, when dissolved, of becoming a basis or mordant, for fixing and modifying some at least of the different adjective animal or vegetable colouring matters, with more or less advantage, by dying. But besides this property, which will be made a subject of future consideration, several metals and semi-metals afford coloured solutions or oxides, which are capable of being united and fixed directly in the fibres of linen, cotton, silk, or wool, and of thereby producing various permanent substantive colours. It is indeed true, that hitherto but few metallic preparations, excepting those of iron and copper, have been used in this way, or for this purpose; I mean that of giving substantive colours.

Iron.

This, by whatever means dissolved, possesses so much affinity to linen and cotton,* that when

* The affinity between cotton and the oxide of iron is so strong, that by simply moving the former about in water, wherein the sulphate of iron has been dissolved, and left exposed to atmospheric air for a few days, it will gradually attract and take to itself every particle of the metallic oxide.

applied to them, its oxide or calx decomposes and fixes itself permanently in their fibres, and thereby produces colours, differing considerably from each other, according to the different states in which the oxide may have been applied, particularly in respect of the portion of oxygene combined with it. But as the oxide of iron, in *all states*, and *however obtained*, is disposed to attract the oxygene of the atmosphere, its different colours, by this addition, soon lose their peculiar shades or variations, and acquire the rusty colour commonly called *iron-mould*. This addition, moreover, soon renders the oxide in some degree corrosive, and joined perhaps to the rigidity which it occasions by a sort of concretion in the fibres of wool, silk, cotton, and linen, it disposes them to become brittle, or less durable. There are few, if any, who have not observed instances of this effect from spots of what is called iron-mould on linens, &c. which produce holes, long before any occur in other places. But where iron is used in dying, merely as the *basis* of animal or vegetable colouring matters, these last, by combining with its particles, lessen their disposition to attract oxygene, and by keeping them farther asunder, so far prevent their concretion, as in a considerable degree to obviate the rottenness in question; though there is but too much reason to fear, that even in this way, stuffs dyed with a ferruginous basis or mordant, are less durable from that circumstance;

and it probably is from the use of this metal, that the rottenness so generally complained of, as accompanying the black dye, principally results.

But in this place I am only to notice the use of iron, as affording substantive colours; and for these, its use is confined to linens and cottons, to which its oxide is very frequently applied, topically, in calico printing, to produce *partial* buff, or rusty yellow, stains or figures, and, in *general* dying, to produce imitations of the nankin brown, as well as a considerable variety of buff colours; for all which purposes, the solutions of iron by vegetable acids are preferred, as being least corrosive, and therefore least hurtful to the fibres of linen and cotton.

Among the vegetable acids, that of vinegar, or alegar, was for a long time almost exclusively employed to dissolve iron, and make that preparation which has been commonly denominated iron liquor (acetite of iron). But, within a few years, another acid has been very frequently substituted for the former; viz. the pyroligneous, distilled from wood. M. Chaptal justly considers this as being truly an *acetic* acid, in combination with a portion of empyreumatic oil, which, instead of diminishing, increases its utility for most of the purposes of dying, and especially for that of dissolving iron;* and when so dissolved,

* "Cet acide," says M. Chaptal, "est préféré au vinaigre

its oxide may be obtained at different degrees of oxidation, but its union with the fibres of linen and cotton, and the colours thence resulting, are most permanent when the oxidation is greatest. M. Chaptal has however discovered, that the various buff, and the imitations of nankin colours, may be greatly improved by combining the oxide of iron with *alumine*, or the earth of alum; and for this purpose, he first impregnates the cotton with the oxide of iron, by working it sufficiently and equally in a solution of that metal by the pyroligneous, or other vegetable acids, or, in default of these, in a solution of the sulphate of iron, marking three degrees on the areometre of Beaumé, and, after wringing it properly, *plunges* the cotton *immediately* into a solution of potash marking two degrees, with which a satu-

pour tous les usages de la teinture et de l'impression sur toile : il porte avec lui une huile qui forme un excellent mordant pour les toiles de lin et de coton, et déjà il remplace l'acide acétique dans les teintures, où il sert à composer ce qu'on appelle le *bouillon noir*, ou le mordant pour les noirs, les violets, les pruneaux, les lilas, les nankins, etc. Les couleurs portées sur ce mordant sont plus nourries, plus vives, et beaucoup plus fixes, que celles que produit l'acétate ordinaire de fer." Chim. appliquée aux Arts, tom. iii. p. 169. He adds, in the next page, " Lorsqu'on veut employer aux usages de la teinture l'acide acétique provenant de la distillation, il est inutile, il seroit même préjudiciable à ses propriétés, de lui enlever l'huile qu'il tient en dissolution."

The pyroligneous acid is dark-coloured, and exhales an empyreumatic odour.

rated solution of alum has been just mixed, but so as *not* to precipitate the alumine. By this last mixture, the colour of the oxide of iron is considerably raised, and it also acquires an agreeable, smooth, even, and *soft* appearance like velvet, which could never be produced with the oxide of iron *unmixed;* it has moreover the advantage of preserving the fibres of cotton from injury by the solution of iron: after being being thus immersed five or six hours, the cotton is to be properly wrung, washed, and dried; and by the last part of this operation, it will generally become deeper, from an accession of oxygene. M. Chaptal distinguishes the varieties of colour dyed in this way, by the names of "nankin, chamois, noisette, et rouillé." Ann. de Chim. tom. 26. p. 270.

The application of pot-ash conjointly with an oxide of iron, *but without alum*, for dying the colours before mentioned, has been practised, particularly at Manchester, for almost half a century. But for this purpose a solution of iron by aquafortis was commonly employed, though injudiciously, as it certainly contributed more than any other, to hurt the fibres of the linen or cotton dyed therewith.* All these

* In the Transactions of the Dublin Society, vol. i. part 1, may be found an account of "a process for dying a nankin colour" by Mr. Richard Brewer. The colour is produced by an oxide of iron; and the process consists of eight troublesome and expensive operations, which do not seem to be compensated by any adequate advantage.

colours, though in other respects very durable, are liable to be spotted, and made black by being accidentally wetted with a little tea, or with the juices, or infusions of a great number of vegetable, and some animal matters, which are capable (as will be hereafter noticed) of producing an ink with iron.

For topical application by the pencil, or block, Haussman recommmends Stahl's alkaline tincture of iron, made by dissolving that metal in aquafortis, and adding to it carbonate of pot-ash *in excess*, sufficient to decompose and *re-dissolve* the nitrous oxide of iron; and afterwards thickening the solution with gum, &c. as usual. Commonly, *however*, a solution of iron by some of the vegetable acids (called iron liquor) is employed for this purpose, adding to it a portion of sulphate of iron, to increase its strength, when very full and deep stains are required.

Iron dissolved by muriatic acid, assumes a greenish colour, and the solution being applied to linen or cotton, the oxide adheres permanently; and, by an accession of oxygene, affords a *fine yellow stain*. A single washing will however so far affect the proportions on which this colour depends as to reduce it to the common iron-mould colour.

Copper.

Only two oxides, or compounds of this metal with oxygene, are known to exist; one of these,

naturally formed, is distinguished by the name of *ruby* copper ore. Its colour is a dark or brownish *red;* though the artificial imitations of it have, I believe, never risen much above an orange colour. This native oxide is supposed to contain about eleven per cent. of oxygene; but neither it, nor any artificial imitation of it, has yet, as I believe, been employed for a substantive colour in dying or calico printing. I however, very recently, and unexpectedly produced, and *fixed permanently* upon calico, a brownish *red* oxide of copper, very nearly resembling the ruby copper ore in colour. It has withstood repeated washings with soap, and six weeks exposure to the weather, without alteration; and may, I think, prove useful, by simple topical application, in calico printing; but in this instance, it was the result of a complicated mixture, made for another purpose, and I have not yet had time to simplify the process sufficiently. When I shall have done so, I intend to make it public. In appearance it resembles another very permanent colour, which I discovered twenty years ago, I mean the *red* prussiate of copper, to be mentioned hereafter.

The other oxide of copper is supposed to contain about twenty per cent. of oxygene; but it has never, I believe, been employed for dying or calico printing.

The *green* colour exhibited by most of the preparations of copper, commonly results from the absorption, or addition of carbonic acid, for which the oxides of copper have a marked affinity; it may be produced also by the admixture of muriatic and some other acids. There is however, I believe, none of the acid green solutions of copper or its oxides, which after being applied simply to cotton or linen will bear to be washed with soap, though their colours generally withstand the impressions of sun and air for a considerable time. But if liquid ammonia be saturated with copper, and thickened with gum, it may, by simple topical application, be fixed upon linen or cotton, where, by an evaporation of a part at least of the volatile alkali, and an absorption, probably, of both oxygene and carbonic acid, its blue colour will be changed to a green resembling that of *verdigrise*, or rather that of the malachite, which will very sufficiently resist the impressions of sun and air, and bear a considerable number of washings with soap without being much weakened thereby. It may, therefore, be usefully employed in this way, especially upon *fine muslins*, by reason of the great delicacy of its colour, and the *facility* of its application. I have several times thought that an effect somewhat better had resulted, when, instead of dissolving the copper by am-

monia, I combined the latter with a *nitrate* of that metal. Verdigrise dissolved by ammonia, also produces good effects used in this manner. A similar beautiful, though pale green, may be substantively dyed upon woollen cloth, by the sulphate of copper with a sufficient portion of carbonate of lime, to neutralize the acid. This colour will not indeed bear the action of soap, but it does not appear to suffer any considerable change or diminution, by the impressions of sun and air for a long time.

The oxides and solutions of copper are all susceptible of combination with most of the adjective colouring matters, and may be usefully employed as mordants or bases with some of them, which will be duly noticed hereafter.

Gold.

When this metal is dissolved in nitro-muriatic acid, the result, as Proust has observed, seems to be a pure and simple muriate of gold: and when beaten into leaves, and burnt by electricity, or calcined by the sun's rays, concentrated and reflected by a burning mirror, it affords a *purple* oxide: and this it also does when precipitated from aqua-regia by the muriate of tin. In this last operation, as well as in the former, the purple colour depends entirely upon the oxide of gold; that of tin, though combined with it, being colourless. This precipitate has been

called the purple of Cassius, though improperly, because it was known to earlier chemists, particularly Neri, Glauber, and Kunkel. The supposed oxides, or precipitates of gold, obtained by mixing either of the alkalies, or lime or magnesia with a solution of gold, are yellow; but such precipitates appear (as Davy has observed) to be triple compounds. Having soaked muslin in a diluted solution of gold by aqua regia, for a single minute, I exposed it whilst wet to the direct rays of the sun in the month of September, and found, in less than a quarter of an hour, that the fine yellow colour which it had received from the muriate of gold, was become partially *violet*, excepting only a few round spots, to which I had previously applied a solution of crystals of soda thickened with gum; in these spots the alkali had neutralized the acid, and produced a colour resembling that of bright iron-mould, upon which the rays of the sun made no impression, or change; the violet colour, so produced, soon became general, excepting the spots last mentioned; and, by a further exposure to the sun's rays, this colour was gradually reddened, and converted to a sort of crimson purple, in consequence, as I presume, of a farther de-oxygenation of the metal, which, from this progressive change of colour, appears to be susceptible of different degrees of oxidizement. A similar change was

produced, much more expeditiously, when I applied a recently-prepared muriate of tin to cotton, impregnated with a solution of gold in aqua-regia, and dried in the dark; an abstraction of oxygene, and a partial revival of the gold, having been almost instantaneously manifested, by the appearance of a violet colour, where the muriate of tin had been applied, and in no other part. Count Rumford, also, (as is stated in the Phil. Trans. for 1798) produced a purple colour by impregnating white silk, linen, and cotton, with a solution of gold, and exposing them to the direct rays of the sun, but he had previously separated a great part of the nitro-muriatic acid, employed to dissolve the gold, by evaporating the solution to dryness, and afterwards re-dissolving the oxide, or salt of gold, in water; a precaution which I did not employ. He found, (as I have done) that no change of colour took place in the dark; but here it must be observed, that he made no trial of the de-oxygenating power of the muriate of tin, which, when employed by me, readily produced the violet colour without the aid of light.*

* More than half a century ago, Hellot had observed that characters traced on writing-paper with a diluted nitro-muriate of gold began, after a few hours exposure to the *air*, (he should have said *light*,) to manifest colour, and soon after became of a very dark violet—" violet foncé presque noir." But when shut up in a close box, he says, the writing did not become

Antecedently, however, to count Rumford's experiments, Mrs. Fulhame (in an essay on combustion, published in 1794) had given an account of several ingenious attempts not only to fix the oxides of gold upon silk, but to revive the gold afterwards with its *metallic lustre*, principally by the application of hydrogene gas, and phosphuretted hydrogene, which in some degree produced the desired effect, though it was found impossible to make the revivification so generally equal, as to produce that uniformity of gilding, which could alone compensate the expence of it.

In consequence of Mrs. Fulhame's publication, count Rumford attempted a more complete revival of gold, by mixing with his aqueous solution of its salt (before mentioned) sulphuric ether, which soon attracted and united itself with the gold, swimming upon the surface and leaving the water colourless: and this mixture being afterwards exposed to the rays of the sun, the metal soon revived in the form of gold leaf.

Such a mixture of sulphuric ether and the salt of gold has lately been found *useful to gild the points of lancets*, and protect them from

visible during several months. And he adds, that the like happened to characters written with a diluted nitrate of silver, though they became very visible in the space of an hour when exposed to the sun's rays. See Mém. de l'Acad. R. &c. 1737.

rust; and if the expence be not too great, I am persuaded that white silks might be permanently gilt with it, *in spots* or figures, for which a perfect equality in the metallic appearance of the gold would not be required.

That precipitate of gold by tin, which has been commonly called the purple of Cassius, was soon after its discovery combined with glass to imitate *Rubies*, which it did perfectly, at least in their appearance, though not in their hardness; and in later times, this precipitate has been generally employed as a finer sort of enamel for porcelain, &c. By varying the proportions of tin, or rather of its solution, the colours of this precipitate may be varied through all the intervening shades from violet to crimson; and the precipitate, with all its various colours, may be permanently fixed as a stain or dye upon silk, linen, or cotton, by applying to them, either the solution of tin first, and afterwards the solution of gold; or the solution of gold first, and afterwards that of the tin: it will be advantageous, however, to let the silk, &c. to which one solution has been applied, become dry before the second is superadded.

Lately Haussman has found means to produce a purple mixture of tin and gold, *without any precipitation*, by dissolving the metals with a great *excess* of the acids; which excess re-

tains the oxides, suspended in the water, notwithstanding their union, and such a partial deoxygenation of the gold, as is necessary to its violet colour.

In this purple liquor diluted, silk may, as he says, be made to receive the most durable colours, by *repeated immersions*, &c. which are, as I presume, necessary, by reason of the redundant acidity of the liquor. I do not, however, think that any benefit can result from thus applying the solutions of these metals *mixed*, and *at the same times*, rather than *separately;* for in the latter way two immersions will be sufficient: and it is to be feared that this purple from gold, notwithstanding its great beauty and durability, will prove too costly for any thing, but a partial application in spots and figures.

In my judgment the principal, if not sole use of the solution of tin, in producing this purple, is that of abstracting oxygene from the gold; an effect which may be produced by other means. I have repeatedly found, that when a solution of gold in aqua-regia was applied to, and suffered to remain upon my fingers, they received a purple stain which nothing could remove, but an abrasion or wearing off of the skin; and I have produced a similar effect from a solution of gold applied to silk, cotton, and linen, previously impregnated with matters suited (in like manner) to abstract oxygene;

such as animal glue, lintseed oil, caustic alkalies, yolks and whites of eggs beat up with sugar, or with orpiment, alkaline sulphurets, &c. &c.; and, cæteris paribus, I have found that the more the oxide of gold was deprived of oxygene, the more its colour approached to the crimson.

Silver.

The colours to be obtained *substantively* from the metals, excepting those of iron and copper, chiefly depend upon a partial revival of the metal, which revival cannot take place, without its abstraction or separation from the acid by which it has been dissolved; and to promote this abstraction, it is convenient and sometimes necessary to impregnate the linen or cotton intended to be dyed or stained, with some of the animal, alkaline, and de-oxygenating substances just mentioned, as contributing to precipitate and partly revive the oxide of gold.

This observation is particularly applicable to the oxide of silver, which is properly of an olive-brown colour, but is rendered almost black by being deprived of a part of its oxygene, and thereby in some degree restored to its metallic form. The powerful efficiency of the sun's rays in the de-oxygenation of silver has been already noticed at p. 53 and 54.

Leeuwenhoek mentions (Philosoph. Transact. vol. xxiv.), that by touching nitrate of silver,

his fingers were stained black; and that, finding it impossible otherwise to remove the stain, he cut off and burnt the skin, and then examining it by a microscope, he found the silver revived in a multitude of little globules.—"I have ly-"ing on my desk (continues he), a linen hand-"kerchief, which was stained with aqua-fortis, "impregnated with silver, with a large black "spot about as large as a shilling;" and he adds, that having ineffectually tried to discharge the colour by six washings, and by laying the handkerchief out to bleach, he cut out the stained part, burnt it to coal, and viewing it by a microscope, saw thousands of fine silver globules therein. The effect here mentioned to have been produced upon the skin, accords with that which solutions of silver are known to produce in blackening hair, and other animal substances; but in reading this account, I thought it extraordinary that clean linen, impregnated with no animal, inflammable, or alkaline matter, should so far deprive nitrate of silver of its acid, as to produce the effect described; and I repeated the experiment several times without success. At length, however, I took a silver tea-spoon, which had stood half filled with aqua-fortis for several weeks, and which on the hollow inside was become almost black by it, and by the oxygene of atmosphere which it had attracted, and having poured out the more fluid

part of the solution, I rubbed a bit of cambric against the wet oxidated hollow surface, and hanging it up for a few days in the open air, on the south side of a wall, I found the cambric permanently stained of a very dark violet colour. A fine piece of cotton, however, by the same means received only a very slight discoloration. But cotton, when impregnated with soda and the acidulous arseniate of pot-ash, acquired a strong durable slate colour by being touched with diluted nitrate of silver; a drab colour by the same means, when impregnated with soda and sugar; a dark olive brown, with sulphuret of pot-ash (liver of sulphur), and spirit of wine; and the like with soda, liver of sulphur, and sugar; and being impregnated with white of egg, beat up in water with sugar, the cotton received from the nitrate of silver a very strong brownish black; and when caustic vegetable alkali was added, it became a little blacker. The yolk, instead of the white of egg, produced nearly the same effect. All these colours were often washed, and exposed for a long time to the weather, without being changed.*

* During the last twenty years an ink has been sold, and extensively used for marking linen, &c. which it does *permanently,* by means similar to those just mentioned. To prepare this ink, a white precipitate of pure silver is procured, by dissolving that metal in nitric acid, and afterwards separating it from its *alloy,* by suspending in the solution, a thin slip of

Mercury.

The oxides of mercury very easily give up their oxygene, and are, therefore, readily precipitated by the means before mentioned, upon vegetable as well as animal substances, affording generally either black or dark colours, though of but little permanency, because the residue of their oxygene soon separates, and the mercury recovers its fluid metallic form. Nitrate of mercury applied to cotton, which had been impregnated with soda, produced at first a yellow, which soon changed to an olive, and being washed with soap, to a full black colour; but after a few days exposure in the open air, it almost entirely disappeared. On cotton, im-

copper, which by its greater affinity for the acid, throws down the silver in the form of a white powder, which powder being afterwards mixed with an aqueous solution of white glue and gum arabic, forms the ink. But to render this preparation effectual, the linen, &c. to which it is applied by the *pen*, must have previously received an impregnation like some of those which I have recently described, though they are, in *this*, rendered less necessary, because the precipitate of silver retains but a small proportion of acid, as is manifested by its want of solubility in water, which makes it expedient to shake the mixture as often as it is used. The impregnation most commonly employed seems to consist of isinglass, and white animal glue dissolved in spirit of wine, which being applied to the part intended to be marked, is suffered to dry; after which it is fit to be written upon with what is called the ink. Additional means have been sometimes employed to increase the blackness of the latter, but their effect will not last.

pregnated with soda and sulphuret of pot ash, it immediately produced a black, which, by washing and exposure in open air, changed in about ten days to an olive, and soon after disappeared. On cotton, impregnated with sulphuret of pot-ash and spirit of wine, it also produced a black, which disappeared like the former; and with caustic vegetable alkali it produced nearly the same effect. With orpiment, dissolved by pot-ash, it produced a very *deep black*, which stood two or three weeks exposure to the weather; after which the mercury began to revive, in very small globules, and the colour to disappear in spots.*

Platina.

This metal was first discovered at Choco and Santa Fé, in South America, and was not known to exist naturally in any other place, until Vauquelin lately detected it among the grey silver

* I have now before me some *very black* writing upon calico, which states *itself* to have been written with a solution of nitrate of quicksilver, upon calico impregnated by a mixture of soda, liver of sulphur, and sugar, in water: seventeen years have elapsed since this writing was performed, and there is no appearance of that *revivification* of the mercury, which I had experienced when it was used upon calico with impregnations differing but little from that last mentioned.

Professor Gmelin of Gottingen, in his publication, "de tingendo per nitri acidum," &c. mentions the staining of silk with a *copper* colour by mercury, dissolved in nitric acid.

ores of Guadalcanal in Estremadura ; and more recently Dr. Wollaston has examined, and described a small specimen, which had been found in Brazil, intermixed with palladium. See Phil. Trans. 1809.

Proust says, the result of a solution of platina in the nitro-muriatic acid, is (like that of gold so dissolved) a pure and simple *muriate.*

The oxide of platina, at the maximum of oxygenation, is of a yellowish brown colour ; but when heated and deprived of about one half of this portion of oxygene, it becomes green.

Having immersed a bit of fine calico in a diluted solution of platina, by nitro-muriatic acid, it acquired a yellowish orange colour, and this being afterwards dried, I dipped it into a diluted solution of tin by muriatic acid, to see what effect would result from an abstraction of oxygene (which I expected) by the latter ; and to my surprise, I saw the colour instantaneously changed to that of *arterial* blood. This calico being afterwards dried and washed with soap, its beautiful red was thereby made to incline very much to a bright full orange colour, which did not change by subsequent washings, and seems to be permanently fixed. Though somewhat costly, it probably may be susceptible of some useful application to fine muslins in calico printing. In the production of this colour, the solution of

tin seems to act as it does in producing a *purple* with gold.

The solution of platina (without that of tin) being applied to calico, produced a yellow colour, which, when washed, seemed to be permanent, though it was afterwards raised to a bright high orange, by applying to it the solution of tin last mentioned.

The same solution of platina, being applied to calico, which had been soaked in a prussiate of lime, produced a brown colour, which, by washing with soap, became a dark violet, which seems to be permanently fixed. Similar effects were afterwards produced by the prussiate of pot-ash.

Other pieces of calico impregnated severally with sulphuret of pot-ash; with soda, and the acidulous arseniate of pot-ash; with orpiment dissolved by liquid pot-ash; with liver of sulphur and alcohol; and with lintseed oil; and afterwards soaked in the before-mentioned solution of platina diluted, acquired different shades of purple, olive, and brown colours, which, when washed with soap, appeared to be permanently fixed.

Manganese.

The great variety and mutability of colours afforded to water, in different proportions, and of different temperatures, by manganese in com-

bination with pot-ash, was long since observed by Glauber, as is noticed at page 18 of this volume. Whether the alkaline solutions of this oxide are capable of being usefully employed to dye substantive colours, I am unable to decide; my experiments therewith having been too few. I have found, however, that a considerable variety of lasting brown, or dark-coloured stains, may be produced upon bits of linen and cotton, which have previously and severally received the different impregnations before mentioned, by applying to them a diluted sulphate of manganese; and without any such impregnation, if the latter be applied to linens or cottons, and they be afterwards dipped into a weak solution of pot-ash or soda, a yellowish brown colour will be produced; and this, by attracting oxygene, will gradually change to a *dark*, and *very durable brown.* But if to this otherwise lasting dark colour, a solution of tin by muriatic acid be applied, it will restore the former yellowish brown, by causing an abstraction of oxygene from the manganese; though the latter by its affinity for oxygene will afterwards *repair this loss,* and by doing so will restore the former dark brown colour.

Cobalt.

The nitrate of cobalt may be decomposed by liquid pot-ash, and it will then afford a blue pre-

cipitate, which if secluded from atmospheric air will become *violet*, and afterwards *red*.

Nitrate of cobalt applied to cotton, impregnated with soda, with soda and acidulous arseniate of pot-ash, and with caustic vegetable alkali, produced lively pink and rose colours, which stood washing and exposure to weather for a considerable time.

The oxide of cobalt, dissolved by muriatic acid, and applied to cotton impregnated with soda, when held to the fire, exhibited the most beautiful green, which, as the cotton cooled, changed to an apple-green; then passed through all the shades of yellow, and became a kind of pale buff colour, which the oxide retained after the cotton had been washed with soap; but then on being heated, it was found to have lost the property of becoming green, though on dipping it into a diluted muriatic acid, it immediately regained and exhibited the same property. These effects are connected with those which similar solutions of cobalt produce as sympathetic inks; though I confess myself dissatisfied with all the explanations hitherto given of them. The presence of muriatic acid is essential to their existence, the nitrate of cobalt producing no such phenomenon;* nor did I

* Having lately soaked a bit of calico in a diluted nitrate of cobalt, it exhibited a pale rose colour, when dried. To the

find that the presence or absence of light had any effect in retarding or promoting any of the changes of colour here mentioned.

Nickel.

If this metal be dissolved by nitric acid, the solution may be decomposed by pot-ash, and a grass-green hydrated oxide will be thereby obtained. By impregnating calico with a mixture of soda and sugar, and immersing it in a diluted solution of nickel by the nitric acid, a similar green was produced on the calico; but it did not prove sufficiently durable, to be employed in dying or calico printing.

Molybdena, titanium, palladium, and osmium, afford coloured oxides of considerable beauty and variety, which probably might be applied and fixed upon silk, linen, and cotton, were not

calico so coloured I applied a solution of tin by muriatic acid, in *spots*, and afterwards holding the calico to the fire, I soon observed that these spots were all of a most *beautiful blueish green*, whilst every other part retained its rose colour. By removing the calico from the fire, and letting it cool, the spots again became rose-coloured. Having afterwards rinced the calico in water, the parts which had been spotted lost the power of becoming green when *heated*; but by wetting them with muriatic acid, they regained this power, a proof that this acid, and not the tin dissolved by it, had, in the first instance, enabled the fire to produce the blueish green colour.

these metals too scarce and costly, especially the latter, for this use.

Berthollet has mentioned, (Ann. de Chimie, tom. i.) that the simple mixture of an oxide of lead with lime, will blacken wool, hair, &c. and that some persons have used it to render grey hairs black. Wishing to ascertain its effect in dying, I boiled flannel in lime-water with litharge, which produced a tolerable black upon the flannel; and this black was not diminished by washing the flannel with soap, and exposing it for the usual time to the weather: strong acids, however, dissolved the lead, and discharged the colour: and the lime was found to have weakened the texture of the flannel considerably, and more especially when orpiment was *added;* an effect similar to that which it produces in those depilatory compositions which were brought to Europe from Turkey.

Perhaps my readers may think, that many of the preceding experiments are such as the great Bacon (Lord Verulam) has termed "*experiments of light rather than of fruit.*" But such experiments are not to be neglected in a work which professes to treat of the *Philosophy* of Colours, though they should not be susceptible of any considerable *practical* advantage, or application.

With this observation, I finish my account of substantive colouring matters. They claimed

my earliest notice, because their properties and modes of application are generally the most simple and intelligible; and because some of them, particularly the oxides of metals, may also be made to serve as the bases of adjective colours; which will become the subject of our next inquiries.

END OF PART I.

PART II.

EXPERIMENTAL RESEARCHES

CONCERNING THE PHILOSOPHY OF

PERMANENT COLOURS.

PART II.

CHAPTER I.

Of Adjective Colours generally, and their bases; with an illustration of their effects upon each other, as exemplified by Oriental and European calico-printing.

"Les faits sont de tous les temps, ils sont immuables, comme la "nature dont ils sont le langage; mais les conséquences doivent "varier selon l'état des connoissances acquises."

CHAPTAL, *Elémens de Chimie.*

ADJECTIVE colouring matters are generally soluble, in a great degree at least, by water; though some of them derive their solubility from an intermixture of what has been called *extractive* matter; which being separated in the dying process, after the adjective colour has been applied to the dyed substance, their union becomes thereby more intimate and permanent. But in other respects, adjective colours owe their durability, as well as their lustre, to the interposition of some earthy or metallic basis; which, having a considerable attraction, both for the colouring matter and the stuff to be dyed, serves as a bond of union between them,

and obviates that disposition to suffer decomposition and decay, which naturally belongs to such colouring matters when *uncombined*. These earthy and metallic bases, having been commonly employed in a state of solution or combination with acids, were from that circumstance denominated *mordants* (biters or corroders) by the French, who, indeed, began to employ the term long before any thing like a true theory of dying had been conceived; whilst even alum was supposed to act by its sulphuric acid, and not by the pure clay upon which its usefulness depends, and whilst in truth all the other matters called mordants were supposed to be useful only by their solvent or corroding powers; and the term, having been thus employed, has been since adopted in other countries. The ingenious Mr. Henry, of Manchester, has, however, lately objected to it, with great reason,* and proposed in its stead to employ the term *basis*, which seems defective only, inasmuch as it does not express the particular *affinity*, or *power of attraction*, manifestly subsisting between these earthy and metallic substances, and the several adjective colouring matters, as well as between the former

* See his "Considerations relative to the nature of Wool, Silk, and Cotton, as objects of the Art of Dying, &c." in the third vol. of the Memoirs of the Manchester Society.

and the fibres of wool, silk, cotton, &c. I confess, however, that no other more suitable term has occurred to me; and being unwilling to propose new terms, without some cogent reason, I shall sometimes employ that of mordant as well as that of basis; though not indiscriminately in all cases; since I shall generally use the former to signify earthy and metallic substances when *actually dissolved* by some acid, alkaline, or other solvent, and when of course they will commonly prove more or less corroding or biting, according to the original meaning of the term. But the denomination of basis will be most frequently used to designate the same earthy and metallic substances, distinctly and separately from any acid or other solvent, when actually fixed in the pores or fibres of wool, silk, &c. or when it is not intended to notice any property in them, which may more immediately result from their combinations with any particular menstruum. M. Berthollet, indeed, gives the term mordant a much more extensive signification, as meaning all the different chymical agents capable of serving as *intermedia* between the several colouring particles and the stuffs so dyed with them, either for the purpose of assisting their union, or of modifying it.* This last effect (of modification)

* "L'on donne le nom de mordant aux substances qui

may, however, be produced by a variety of matters besides those which are of the earthy or metallic kinds, and indeed by every thing capable, not of fixing, but of merely varying, the shades of adjective colouring matters. These, therefore, I think it more proper to designate, not as mordants or bases, but as *alterants*,* whose use and application may in this respect be extended to substantive as well as to adjective colours.

The bases pre-eminently useful with adjective colours, are the earth of alum, and the oxides of tin and iron, held or applied in solution by an acid menstruum : and, excepting the process for dying black upon woollens and silks, it is generally deemed most advantageous to combine these bases first, and separately, with the stuffs to be dyed, superadding the colouring matters afterwards ; because the affinity or attraction of the basis, is commonly greater for the latter, than for either wool, silk, cotton, or linen; particularly that of the earth of alum, which, when applied subsequently to,

servent d'intermèdes entre les parties colorantes et les étoffes que l'on teint, soit pour faciliter leur combinaison, soit pour la modifier." *Elémens de l'Art de la Teinture*, tom. i. p. 26, of the first edition.

* M. Berthollet, in his *last* edition, tom. i. p. 71, has adopted the term of *alterants*, and employed it in the way which I had suggested, as above, in my first publication.

and upon the colouring matter, forms with it a kind of lake, by which their respective affinities are in a great degree exerted towards, and saturated by each other; and the size of their particles being thereby increased, they do not penetrate copiously into, nor combine intimately with the fibres of wool, silk, &c.; but remain in a great degree suspended in the dying liquor, or precipitated to the bottom of it. But by combining the basis *previously*, and separately, with the stuff to be dyed, and afterwards applying the colouring matter, this last, when so applied, is powerfully attracted by the conjoined affinities of the former, so that the dying liquor may be completely exhausted, and made colourless thereby.

It must, however, be noticed in regard to *wool*, that by reason of its *greater* attraction for metallic oxides, they may, without any considerable disadvantage, be applied to it, in conjunction with adjective colouring matters, as will be mentioned in regard to the dying of *scarlet* and some other colours. It ought also to be observed, that when colours are dyed upon wool, silk, &c. by the aid of an aluminous or metallic basis, the colour is applied, or dyed more immediately upon the latter, than upon the wool or silk, &c. as will be made evident hereafter. The durability therefore of an adjective colour must depend, not only on the

natural stability of the colouring matter, but also upon the energy of its affinities, both for the stuff which is dyed, and for the basis or intermedium upon which it is immediately applied, and which, by its own peculiar attractions, binds them to each other.

The true nature and uses of mordants or bases, for the purposes under consideration, can, I believe, in no way be so distinctly manifested, or so clearly illustrated, as by their effects in what I shall call *topical* dying, or that species of it by which different colours are communicated to particular spots or figures on the same piece of cotton or linen, according to the several bases previously applied thereto, and which principally constitutes that truly wonderful art, the art of calico-printing. I shall, therefore, in this place, bring under my reader's notice some of the more important operations of that art, reverting at the same time, as far as we can, towards its remote origin, in order to see how, and by what means, it has attained its most important improvements.

Pliny describes the Egyptians as practising a species of topical dying, or calico-printing, which, as far as can be discovered from his general terms, appears to have been similar to that which, many ages after, was found to exist in Hindostan and other parts of India, and was from thence introduced into this and

other countries of Europe. He says, the Egyptians began by painting or drawing on white cloths, (doubtless linen or cotton,) with certain drugs, which in themselves possessed no colour, but had the property of attracting or absorbing colouring matters. After which, these cloths were immersed in a heated dying liquor; and though they were colourless before, and though this dying liquor was of one uniform colour, yet when taken out of it soon after, they were found to be wonderfully tinged of different colours, according to the different natures of the several drugs which had been applied to their different parts; that these colours, so wonderfully produced from a tincture of only one colour, could not be afterwards discharged by washing; and he considers it as admirable, that the dying liquor, which, if cloths of different colours had been put into it, would have *confounded* them all, should thus produce and permanently fix several colours, being itself only of one.*

* "Pingunt et vestes in Ægypto inter pauca mirabili genere, candida vela postequam attrivere illinentes non coloribus, sed colorem sorbentibus medicamentis: hoc cum fecere, non apparet in velis: sed in cortinam pigmenti ferventis mersa, post momentum extrahuntur picta. Mirumque, cum sit unus in cortina color, ex illo alius atque alius fit in veste, accipientis medicamenti qualitate mutatus: nec postea ablui potest. Ita cortina non dubià confusura colores si pictos acciperet, digeret eos ex uno, pingitque dum coquit." Plinii, l. xxxv. cap. ii.

Whether the Egyptians borrowed this wonderful art from the Hindoos and other inhabitants of India, or whether the latter borrowed it from the Egyptians, is a question which probably may be answered without much difficulty, if we consider the many reasons which exist for believing that this art has been practised over a great part of India during a long succession of ages; that not only the art itself subsisted there, but that the colouring and other materials for exercising it, were the natural and *peculiar* productions of that country, rather than of Egypt; that the Indians were highly civilized at least twenty-two centuries ago, during which space of time their manners, sanctified (if I may so express myself) by being connected to their religion, suffered little, perhaps no change; that their trades were carefully perpetuated in particular families; and also that among these their manufactures were undoubtedly of very great antiquity, whilst obvious ways, by which they might have been easily extended to Egypt, and other countries, undoubtedly existed long before the time when Pliny wrote.

Major Rennell observes, that "a passion for "Indian manufactures and products has actuated the people of every age, in lower Asia, "as well as in the civilized parts of Europe: "the delicate and unrivalled, as well as the

"coarser and more useful fabrics of cotton of "that country, particularly suiting the inhabi- "tants of the temperate regions along the Me- "diterranean and Euxine seas. To this trade "(continues he) the Persian and Arabian Gulfs "opened an easy passage; the latter particu- "larly, as the land carriage between the Red "Sea and the Nile, and between the Red Sea "and the Mediterranean, took up only a few "days. It is highly probable, and *tradition in* "*India* warrants the belief of it, that there "was from time immemorial an intercourse be- "tween Egypt and Hindostan, at least the "maritime part of it; similarity of customs in "many instances, as related of the ancient "Egyptians by Herodotus, (and which can "hardly be referred to physical causes,) exist- "ing in the two countries."—"It would ap- "pear, that under the Ptolemies the Egyptians "extended their navigation to the extreme "point of the Indian Continent, and even "sailed up the Ganges to Palibothra." See Memoir and Map of Hindostan, &c. 4to. by James Rennell, F. R. S.

The best accounts of the practice of *calico-printing** in the East Indies, were given in cer-

* I here continue to use this term, though in truth none of the mordants or colouring matters, employed to stain the calicoes of India, were applied by engraved blocks or plates as in Europe, but by the pencil.

tain letters, written by Father *Cœurdoux*, a missionary at Pondicherry, (published in the xxvith Volume of "Recueil des Lettres Edifiantes, "&c.") with the supplemental remarks and corrections of Mons. Poivre; and in a manuscript account procured from thence by Mons. Du Fay, and communicated to the Royal Academy of Sciences at Paris, by the Abbé Mazeas;* and also in the report made in 1735 by M. Beaulieu, (then a captain in the French navy) of the operations which, at the request of Du Fay, he caused to be performed under his *own inspection*, at Pondicherry, and by which a piece of chintz was completely printed or stained of various colours, as described in a little publication, entitled "Traité sur les toiles peintes, dans lequel on voit la manière dont on les fabrique aux Indes," &c. From these several accounts, as well as from some valuable private information which I have been able to procure, the following concise statement has been composed, of the principal operations by which the chintz calicoes of India received the colours for which they were highly celebrated before the art of

* "Recherches sur la cause physique de l'adhérence de la couleur rouge aux toiles peintes qui nous viennent des côtes de Malabar & de Coromandel:" par M. l'Abbé Mazeas, correspondant de l'Académie, &c. Mém. des Sçavans Etrangers, tom. iv.

calico-printing had been introduced and simplified in Europe. The cotton cloths, when brought from the weaver, partly bleached, were worn next to the skin, by the dyer and his family, during the space of eight or ten days; after which they underwent several macerations in water with goat's or sheep's dung, accompanied by frequent intermediate beatings, washings, and dryings (by exposure to the sun.) Afterwards they were soaked for some time in a mixture of the astringent external part of the fruit of the yellow myrobalan tree,* (separated

* The fruits of several trees not yet accurately distinguished, or ascertained, have been called myrobalans: that species which is here meant, belongs to the genus *terminalia*, to which the trivial or specific name of chebula, or that of citrina has been applied. See Retzius's Observations. It is the *badamier* of the French, and *her* of the Hindoos. The ripe fruit is yellow, and pear-shaped, with five longitudinal angles; and, when dried, appears wrinkled. It consists of a white pentangular nut, covered by a mucilaginous and highly astringent substance, nearly two lines in thickness; and within the nut is a small white oily kernel. The nuts are separated from the astringent substance which covers them, by bruising the fruit under a wooden roller or cylinder, it being the external astringent substance only, or an infusion or decoction thereof, which is generally employed throughout India for dying or calico-printing, and which, by very decisive experiments, to be mentioned hereafter, I have found to be capable of answering all the purposes of *galls*. Indeed, the leaves of this tree afford a sort of flattish yellow irregular *galls*, produced by the punctures of a particular species of insect; which galls are collected and sold in all the

from the nut and powdered) with buffaloes' milk; and being thoroughly penetrated and impregnated therewith, they were taken out, and the liquor being well squeezed from them, they were again dried by exposure to sun-shine, and afterwards, by pressure and friction, with wooden rollers, they were made smooth enough to be drawn upon by the pencil, with the different mordants (according to patterns previously traced out and marked by powdered charcoal). The first of these mordants was an iron liquor (acetite of iron), similar to that since employed by the calico-printers of Europe, excepting only that, instead of vinegar or alegar, the iron was dissolved by a mixture of sour palm wine, and of water in which rice had been boiled.* This

bazars or markets: they are called *aldecay* by the Telingas, or Hindoos of the Circars, and cadacay or caducay by the Tamuls: and they produce with iron a strong durable black dye, and ink; and with alum a very full, though dark brownish yellow. If hese galls were bruised so as to occupy less space than they otherwise must, by reason of the cavities contained within them, they might be advantageously imported into this country, as might also the external astringent substance of the fruit of the terminalia chebula separated from its *useless* nut. By some persons the unripe fruit is preferred, as having most acerbity or astringency.

* In the letters of Father Cœurdoux, the water in which rice had been boiled, and which was converted to a sort of vinegar, is termed canje, and the vinegar from palm wine is named callou. In these, bits of old iron and the vitrefied matter of a smith's forge powdered, were macerated and exposed

liquor was applied to the figures or spots intended to be made black, by a combination of the oxide of iron, with the colouring matter of the myrobalans.

By this method of producing black stains, the colouring matter is applied previously to the metallic basis, contrary to the practice in regard to most other colours. But in this the strong attraction of oxide of iron for the fibres of cotton, as already mentioned, obviates the evil which would result from a similar application, where *other* mordants were intended to follow.

When the black figures or stains have been thus produced, the blue are next to be given, and as a preparation for this, it is thought necessary to remove the astringent and oily matters which the calico had imbibed in every part, by being soaked in the mixture of buffaloes' milk, and powder of myrobalans; and for this purpose it is macerated during 24 hours in the dung of goats, or sheep, diluted with water, then rinced thoroughly and repeatedly in clean water, and dried in the sun: after which the figures intended to be made blue, are marked by outlines traced with powdered charcoal mixed with a solution of gum; and this being done,

to the sun, until a sufficient solution had been effected. According to Dr. Roxburgh, the Telingas give the name of *cassim* to their solution of iron, made by palmira toddy, or the juice of Borassus flabelliformis, (a species of palm) turned to vinegar.

every other part not intended to be made blue, is covered with melted wax, to protect it from the indigo: and then the calico is sent to the blue dyer, and by him immersed in the *cold* indigo vat described at p. 203; and being sufficiently dyed, the wax is afterwards removed by covering the calico with boiling water, which melts the wax, and this last rising to the top, is separated when the water cools. But as the wax cannot in this way be completely removed, the calico is again soaked in a mixture of goats' or sheep's dung and water, rinced, dried in the sun, beat and afterwards soaked and boiled in water with *olla*, or washermen's earth, (which seems to be a natural mixture of soda and chalk) then macerated in water with cow-dung, and again well rinced, dried in the sun, and beat. After all these operations, the calico is again to be impregnated with the same oily and astringent matters which were removed to make way for the indigo blue, by soaking it again in the mixture of buffaloes' milk and myrobalan powder, drying and making it smooth, as before. And this being done, the calico will be in a fit condition to receive the aluminous mordant, upon which the red is afterwards to be dyed; which mordant is to be applied according to figures marked out with powdered charcoal: and when purple and violet figures are to be produced, they are to be in like manner

designated; and for these, a mixture of the solution of iron, with the aluminous mordant, in suitable proportions, is to be applied; whilst for the figures intended to be *red*, the aluminous mordant *alone* is employed as a basis. These mordants are commonly applied by children, with the pencil, or with pointed wooden sticks.

To prepare this aluminous mordant, two ounces of alum were dissolved in two quarts of water, taken from certain pits, which water Father Cœurdoux has called "apre," probably because it held in solution a little soda, which there abounds in many places. To colour this solution, so that the strokes of the pencil in applying it might be visible, a little sappan or sampfan wood (cœsalpinia sappan of Linn.) in powder, was steeped in the solution, which being afterwards strained, was applied as before mentioned; after which the cotton so penciled, was exposed to the hottest sun-shine, in order that the parts to which the mordants had been applied, might be dried as much as possible; and then the cottons were thoroughly soaked in large pits of water, to cleanse them from the loose superfluous parts of the different mordants, as well as from the buffaloes' milk, &c.; and this being done, they were slowly dyed in water moderately heated, with certain roots answering nearly in their effects to those of madder. Of these there are several sorts used for

dying red in different parts of India, which will be more particularly noticed hereafter; that pointed out by the accounts in question, and most commonly employed, is called on the coasts of Coromandel and Malabar by the names of chay, chaia, chayaver, chailliver, and raye de chaye.* And after being dyed, the cottons underwent three different washings with goats' dung, soap, &c. and were then bleached by being exposed to the sun, and watered occasionally, to remove the stain on the parts intended to be left white.

It appears, that in this operation the buffaloes' milk, and more especially the astringent juice of the myrobalans, produced very beneficial and important effects, by their attraction for the aluminous earth, which contributed greatly to decompose or separate it from the sulphuric

* This root was supposed, by M. M. Poivre, Hellot, and others, to be a species of *galium* or lady's bed-straw; afterwards, however, M. Duhamel de Monceau thought there was sufficient reason to consider it as the Hedyotis herbacea Lin.: lately, howéver, Dr. Roxburgh has ascertained it to be a species of *oldenlandia*, to which he has annexed the specific name of umbellata; (see Plants of Coromandel, vol. i, p. 2, t. 3.) This indeed belongs to the same class and *order* as the galium and hedyotis (i. e. to the tetrand. monog. Lin.); and is called tsherivello by the Telingas; ché, saya-ver, and imbourel, by the Tamuls. Since my former publication on this subject, I have made numerous experiments with this root, of which an account will be given hereafter.

acid, and consequently to fix it more firmly in the cotton ; and being so fixed, it was enabled more strongly to attract and retain the colouring matter of the chay root when in the dying vessel, and thereby to produce a more permanent red colour in the different spots, figures, or designs, where the alum liquor had been applied.*

The astringent or colouring matter of the myrobalans also contributed essentially to produce the purple and violet stains, upon the parts or figures to which, for that purpose, a mixture of iron liquor and of the aluminous mordant had been applied, as lately mentioned; the chay root *not* having (as my experiments prove) the property, like madder, of producing those colours with iron.

After these operations, a *yellow* composition was applied by the pencil, &c. to the parts which had been preserved white ; and when a

* When a solution of alum is applied to calico which has received no impregnation, it will not be sensibly decomposed ; but on the contrary, a great part of it will again crystallize, so soon as the water which held it in solution has evaporated ; and none but very feeble colours can be raised upon such a basis. But when calico has been impregnated by such astringent and animal matters as are obtained from myrobalans and buffaloes' milk, the alum will not only be decomposed, but the alumine will combine with the astringent and oily matters so obtained, and a basis will be laid for a colour almost as durable as the Turkey red.

green was wanted, to other parts which, with a view to that colour, had been dyed blue. This *yellow* composition was made by dissolving powdered alum in a decoction of the powdered galls of the myrobalan tree, called *aldecay* by the Telingas, &c. as just mentioned. In making this decoction, powdered turmeric and dried pomegranate rinds were sometimes put into the water, with the aldecay. But the yellow or green resulting from this application, will only endure a few washings, before it becomes almost obliterated. Father Cœurdoux pretends, indeed, that this defect may in a great degree be obviated by mixing with the yellow in question, some of the astringent juice of the root of the plantain *(musa)*; but if this had been true, such mixture would doubtless have been employed, and in that case the yellow of the Indian chintz would not have proved so defective, as it is known to have been at all times.

In this composition we have an adjective colour directly combined, and topically applied with its basis, instead of being applied separately, as is most usual. Such compositions (which will be frequently mentioned hereafter) assume the form of a substantive colour, without being such in reality; and as it may be useful to distinguish them by an appropriated term, I beg leave to call them *pro-substantive topical colours*, and to apply that designation wherever

an adjective colour, and its basis or mordant, are thus mixed and applied together *topically*, either by the pencil or the block.

The art of calico-printing, since its introduction to Europe, has been divested of many tedious operations and manipulations, which indeed would have proved insupportably expensive here, on account of the higher price of labour, and of almost every thing necessary to human subsistence.* But the greatest European improvement in this art, respects the aluminous mordant, and depends on the employment of sugar of lead (acetite of lead), or the oxide of that metal dissolved by distilled vinegar, and crystallized; which within the memory of man has been gradually brought into use, without any theory, or even suspicion of its true effect, or of the way in which it has proved so highly useful. This improved aluminous mordant is now generally made by dissolving three pounds of alum in a gallon of hot water; then adding one pound, or in some particular cases one pound and a half, of the acetate or sugar of lead, stirring the mixture well during two or three days,

* Berthollet, tom. i. p. 8, of his last edition, has delivered a similar opinion, and he adds in a note, " Cette opinion est confirmée par les détails *plus exacts* que l'on trouve dans Bancroft *Of Permanent Colours*." — He considers the art of dying in India as being now nearly in the state in which it was at the time of Alexander's invasion.

and afterwards adding to it about two ounces of pot-ash, and as many of clean powdered chalk (carbonate of lime). In this mixture, both the alum and the sugar of lead are decomposed by a double elective attraction, which produces two new compounds, according to Mr. Henry and M. Berthollet, because the oxide of lead having a stronger attraction for the sulphuric acid than for that of the vinegar, combines with the former, and, forming an insoluble salt, subsides to the bottom of the liquor, whilst the earth of alum, thus left in a very divided state, unites to, and is dissolved by the acetic acid, previously separated from the lead, and remaining in the liquor, which thereby becomes a diluted acetate of alumine; the pot-ash or chalk only serving to neutralize the excess of sulphuric acid, which is always contained in alum, and which would in some degree hinder the alumine from being deposited and fixed in the fibres of linen and cotton. But the decomposition here described takes place only *in part,* because one pound of sugar of lead, or even one and a half, (the greatest quantity any where proposed,) is not sufficient to decompose three pounds of alum. On the contrary, I have found that alum cannot be completely decomposed, without nearly its weight of sugar of lead :* and where

* Having added a pound of sugar of lead to a pound of alum

less has been used, I have always been able, by evaporation, to detect a quantity of it in the aluminous mordant. I shall have occasion hereafter to revert to this subject, and shall therefore content myself at present with remarking, that the printer's aluminous mordant is not, in fact, a mere solution of the alumine, or earth of alum, by the acid of vinegar, as those eminent chemists Mr. Henry and M. Berthollet have supposed; but that even with the greatest proportion of sugar of lead ever employed by the calico-printers, it contains a considerable por-

dissolved in hot water, I found that though the alum was decomposed and a pure acetate of alumine produced, yet the acetic acid, which had dissolved the lead was not sufficient to re-dissolve the whole of the alumine, a part of it having subsided with the sulphate of lead; it was, however, soon dissolved by adding vinegar to it; and this solution, when made with strong vinegar, proved as efficacious as the pure acetate of alumine in fixing the colours of madder, &c.

Gay Lussac has observed that an acetate of alumine, which when cold is perfectly *transparent*, becomes turbid and deposits a part of its alumine when heated, and that if left to cool again, the aluminous sediment will be re-dissolved, and the liquor recover its former transparency: an effect which he thinks analogous to the coagulation of albuminous matter by heat, of which he has given an explanation in p. 107 of the 74th volume of the Annales de Chimie. The fact however it may be explained, enables us to understand (what experience had in some degree previously suggested) why the aluminous basis *should not* be applied *warm*, when it is intended to be copiously fixed on calico, under the operation of printing.

tion of alum in its original state; I mean that in which the argillaceous earth or alumine is combined with sulphuric acid. But, notwithstanding this circumstance, I shall generally consider this preparation as being in reality, what it is not strictly, an acetate of alumine; and shall commonly distinguish it either by that name, or by that of the printer's aluminous mordant.

The mixture or mordant in question being thus made, and the clear liquor decanted from the sediment, it is afterwards thickened with flour,* if intended to be printed or applied by

* Since my former edition, it has been found that by slightly torrefying the flour, it was rendered more soluble in water, and more suitable for the purpose of giving consistency to the mordant in question; and the *brown* colour which it acquires by torrefaction supersedes the use of Brasil wood, and other colouring matters, to mark the parts which have received the mordant. Starch, by a similar torrefaction, softens, swells, and emits a penetrating odour; and, the torrefaction being *then* stopped, a substance is obtained, which has been lately much employed by calico-printers as a substitute for the gum of Senegal, under the name of British gum.

From half to three quarters of a pound of gum have commonly been found necessary to each quart of the mordant, according to the season of the year, and the sort of figures or impressions intended to be made. So much consistency should be always given to the liquor as will hinder it from spreading beyond its proper limits, taking care at the same time, that it shall retain so much *fluidity*, as thoroughly to penetrate the fibres of the calico, and, in the language of the printers, serve as a *leader* or conductor to the alumine, &c.

the block and with the gum of the mimosa nilotica (gum arabic), or of the mimosa Senegal (gum of Senegal), if it be intended for pencilling; and being applied in either of these ways to linens or cottons, previously bleached and made smooth by the cylinder, the latter are to be *thoroughly* dried* by a *stove heat* of 150 deg. of Fahrenheit, and afterwards put into a copper partly filled with a mixture of *cow dung* and water, through which they are to be turned by the winch, backwards and forwards, until the gum or flour employed to thicken the mordant has been dissolved, and the loose particles of alumine separated; that they may not in the dying vessel combine with the colouring matter, and discolour the grounds intended to be preserved white. The cow dung in this operation was supposed to be useful only by combining with, and entangling the superfluous parts of the mordant, so as to hinder them when sepatated from the figures to which they had been first applied, from attaching themselves improperly to other parts, and becoming the basis of an unpleasant stain. But there is reason to believe that cow dung, by the gastric juices,

* This thorough desiccation, by artificial heat, contributes very much towards a more *perfect union* of the aluminous and ferruginous bases with the fibres of the cotton, by causing an evaporation of the acetic acid, and also of the water, which by their affinities, would obstruct the desired *union*.

gelatine, and albumen, which it contains, affords a very beneficial impregnation to the printed calico, of some animal matter, which combining with the mordant, serves to bind it more strongly to the printed calico, and afterwards to increase its attraction for the colouring matter, like some of the *animal* impregnations which are so necessary for the Turkey red.*

* Mr. Watt has supposed that the animal *gall* contained in cow dung, exercises a particular power in this operation, of separating the acetic acid from the alumine, and that by combining with the latter, it renders it more efficacious afterwards, in attracting and holding the colouring matter in combination. Mr. Widmer, of Jouy, near Versailles, has entertained nearly a similar opinion, (as Berthollet reports) ; he believing that, " dans le bouzage il se forme une combinaison *triple* de la matière animale avec l'alumine et la toile, qui ajoute à la beauté des couleurs :" and for this opinion, Berthollet thinks there is some foundation, because water alone does not answer the purpose ; and he adds, that an examination, *not indeed the most minute,* of cow dung, did not enable him to discover in it any thing likely to produce these beneficial effects, excepting a matter analogous to *bile,* " une matière analogue à la bile." Elémens, &c. tom. i, p. 90.

Haussman substituted powdered chalk for cow dung (with water) ; but found the colours which were raised afterwards upon the aluminous basis to be very feeble, though those upon the oxide of iron, which had at the same time been subjected to the action of chalk and water, did not appear greatly defective. Soap and water being employed instead of cow dung and water, produced effects more hurtful to the aluminous basis than those of chalk and water. If cow dung were only useful by *thickening* the water, oatmeal, or the meal of lintseed might well supply its place ; but I have not found them capable of doing so.

Subsequently to this dunging operation, the pieces of calico are to be well rinced, and beat in clean running water, to remove as far as possible every loose particle of the mordant, which might otherwise, when in the dying vessel, occasion an improper stain.

By thus substituting the acetic for the sulphuric acid, in the aluminous mordant lately described, several considerable advantages are gained. The acetate of alumine being much more soluble in water than common alum, the liquor will contain a much larger proportion of alumine, than could be otherwise suspended in it; and with this advantage, moreover, that it will not be liable to form crystals in or upon the linens or cottons in drying, as would happen with a solution of common alum, the acetate of alumine being incapable of crystallization. I may add also, that the acid of vinegar being volatile, and having a much weaker attraction for its earthy basis than the sulphuric acid has, the former will be speedily separated and carried off, especially by the heat of the stoves employed for drying the pieces printed with it, and will leave behind the alumine which it had dissolved, and which, being no longer encumbered by any other attraction, will yield itself wholly to that, which subsists between it, and the fibres of linen or cotton, and will unite with them more copiously and firmly

than it otherwise could do, and be thereby enabled more strongly to attract and fix the colouring matters in the dying vessel. This, however, will only prove true, so far as the sulphate of alumine has been really decomposed by the acetate of lead, or so far as the alumine has been combined with the acetic instead of the sulphuric acid.*

* Since these observations were first published, *cheaper* means have been discovered of forming an acetate of alumine. White lead, not adulterated by carbonate of lime, being dissolved in strong vinegar, was found, in several experiments which I made, to answer the purpose of sugar of lead, and to produce a good aluminous mordant, by adding to the solution a suitable proportion of powdered alum; and I afterwards found that litharge dissolved in vinegar, instead of white lead, was equally useful for decomposing alum. But soon after it had been ascertained, that the acid obtained from oak, beech, and other woods, by converting them to charcoal in *close vessels*, and collecting the acid by proper tubes and receivers, was truly an acetic acid with only an intermixture of an empyreumatic oil, and perhaps a little ammonia, this pyroligneous acid was generally substituted for vinegar, and employed to dissolve the oxide or carbonate of lead; and the solution so made, was, with a considerable diminution of expence, employed to decompose alum, instead of sugar of lead; the empyreumatic oil, excepting its unpleasant smell, doing little or no harm even to the most lively and delicate colours, and proving in some degree beneficial to those depending on a ferruginous basis.

More recently, however, it has been discovered, that by dissolving lime instead of an oxide or carbonate of lead, in the pyroligneous or other acetic acid, alum might be still more

As the practice of calico-printing has been but lately introduced into Europe, and as the acetated aluminous mordant does not appear to have been previously known in any other country, we might have expected that its discovery in *this*, would have been deemed a matter so important, as to have constituted an æra in the history of the art; and, therefore, I was not a little surprised in finding that no writer had mentioned, and that no calico-printer, of whom I have inquired, could inform me, at what time, or by whom, this mordant was first employed, as the basis of red and yellow colours in calico-printing. My wonder has, however, ceased on this subject, since I have inspected a considerable number of recipes for making the several mixtures employed as mordants, soon after the business of calico-printing began to be carried on with some degree of success here, and in other parts of Europe. In one of these, which seems to have been the earliest, alum, sal ammoniac, saltpetre, red orpiment, and kelp, were directed to be mixed with water. In another, which probably followed this, it was directed that these ingredients should be dissolved in vinegar. In a succeeding recipe, a little sugar

cheaply decomposed; and at present, an acetate of lime is, I believe, generally employed, instead of the acetate of lead, to produce the aluminous mordant.

of lead was directed to be employed, but in a quantity too small to be of any considerable use; I mean one ounce of it for every pound of alum. Afterwards, the calico-printers, without any system or reasonable motive, appear in different instances to have added verdigrise, arsenic, corrosive sublimate, blue vitriol, *litharge*, and *white lead*. By stumbling upon the two last (which alone were of any use), it happened, where vinegar had been also employed, as it commonly was in some shape, that after a variety of decompositions and recompositions, some portion of acetate of alumine was formed, the good effects of which were experienced, though without any true knowledge of the ways and means by which they had been produced. By degrees, however, the printers seem to have increased the quantity of sugar of lead, and several of them to have suspected that many of the other ingredients usually employed for making their mordants were useless. Some of them, therefore, began to omit one, and some another of these ingredients, until at length all the useless ones were laid aside, though without the aid of any chemical reasoning on the subject, and without any one having ever suspected, as indeed few of them do at this day, that the lead which they continued to employ, occasioned any decomposition of the alum, or that the mordant so produced did not really contain

all the lead and other ingredients used to prepare it. Among the useless ingredients before mentioned, corrosive sublimate seems to have been retained the longest, since Mr. Wilson includes it in his recipe, which was published so lately as the year 1786. (See his Essay on Light and Colours, &c.)

It is not wonderful, therefore, that no particular person or period has been noted, or remembered, as distinguishable for the first invention of the acetated aluminous mordant; since the sugar of lead, or other means of forming it, were at first used by chance so sparingly, as to have scarcely produced any better effect than would have resulted from the mere solution of alum, and the alterations and improvements by which the mordant afterwards acquired its present form, I had almost said perfection, were made by such imperceptible gradations, and resulted so much from the random additions and omissions of different individuals, (no one of whom seems to have been guided by any thing approaching to a just theory,) that neither the discovery, nor any considerable step towards it, can properly be referred to any one person or period.

Mr. Henry, justly sensible of the superior advantages of the acetated aluminous mordant in calico-printing, and conceiving it to have really been very anciently known and employed

in those countries where the art was first practised, concludes from thence, that it must have resulted from a very advanced state of chemical knowledge in those countries, at some very remote period, which was afterwards lost, whilst the improvements arising from it in this respect continued to be practised and handed down, through a long succession of ages to the present time. "To have invented (says he) the process of printing, in the manner described by Pliny, the inhabitants of India must probably have known how to prepare alum; they must have been acquainted with the manner of dissolving lead in the vegetable acids; they must at least have been acquainted with the component parts of these salts, and they must have had a knowledge of double elective attractions, &c." In truth, however, the inhabitants of India neither had, nor have they at present, any knowledge of the use of sugar of lead, or of any other preparation of that metal which could produce similar effects in calico-printing; a solution of common alum in water being their only aluminous mordant, and the previous application of the soluble parts of myrobalans and of buffaloes' milk, to their calicoes, aided by a very *hot sun-shine*, and the complete desiccation which it produces, enabling them, without any thing like an acetate of alumine, to give equal durability to their colours. This fact I have learned, not only from all the

accounts published, or transmitted to Europe respecting this point, but from the positive verbal informations of eye-witnesses to the practice of calico-printing in that part of the world, and particularly of a gentleman of great veracity, as well as knowledge on this subject, who formerly carried on the business of calico-printing very extensively in Bengal (principally for account of the East-India Company): and indeed sugar of lead is so far from being used for this purpose there, that within a few weeks I have received a letter from Mr. John Adie, (successor to the gentleman last mentioned,) dated, "Gondelpara, near Chandernagore, the 10th of February, 1792," and mentioning, that he had some little time before been obliged to pay twenty shillings the pound for sugar of lead, in order to prepare a particular colour which I had formerly recommended; so far was this ingredient from being in use there for any such purpose.

We may, therefore, safely conclude, that the formation of an acetate of alumine, and its application as a mordant in calico-printing, was not an oriental discovery; and that it did not result from any knowledge of double elective attractions, or any other extensive chemical knowledge, either in ancient or modern times; since those who gradually stumbled upon and introduced the use of it, were totally ignorant of the decompositions and recompositions which

took place in their mixtures, and always supposed, as all other calico-printers have till lately done, and as most of them now do, that the aluminous mordant really consisted of every thing used in producing it.

To illustrate more plainly the *differences* of *colouring* matter, as well as the action of an aluminous basis upon them, let us examine its effects in a few particular instances: taking a small piece of calico, upon which certain figures and designs had been printed with the acetated aluminous mordant, and which, after being dried, had been cleansed in the usual way, I dyed it in water with saffron;* the water readily extracted the yellow colour of the saffron, and the calico soon imbibed so much of the colour, as to become *equally yellow in all its parts*, without any difference of shade, even where the alumine had been applied. The calico so coloured being exposed to air, soon became equally and uniformly white; the colouring matter of the saffron having no affinity to the alumine: to see, however, whether this last remained fixed in the fibres of the cotton, I dyed the same piece which the saffron colour had thus abandoned, in water with a

* The colouring matter of saffron readily dissolves in water, but is soon destroyed by the rays of the sun; it gives a rich yellow to linen, cotton, &c. but having no affinity for any known basis, it has no permanency, though it will acquire blueish and greenish shades, when acted upon by the sulphuric and nitric acids.

little Brasil wood, and the figures, where the alumine had been applied, became of a strong, full, and beautiful crimson; the other parts, to which no basis had been applied, being but slightly discoloured. The calico so dyed, being exposed to the sun and air two or three days, the spaces to which no mordant had been applied, became perfectly white; and the figures impregnated with alumine, had lost some of their fine crimson colour, which gradually diminishing, by a continued exposure, was all gone at the end of eight days. In this instance, the aluminous basis had a certain affinity with the colouring matter of the Brasil wood, (which was not the case with that of saffron,) but not so much as to fix and retain it *permanently*. To ascertain, however, that the defect arose from the want of a sufficient affinity between the colouring matter and the alumine, and not between this last and the cotton, I took the same calico, which had been already twice dyed, and dyed it a third time in water with madder, whereby the whole became coloured, but the figures impregnated with alumine much more deeply than the other parts; a proof that the alumine still remained fixed, notwithstanding the escape of the Brasil wood crimson, and that it had again entered into a triple combination with the madder colour, and the fibres of the cotton. The piece so dyed, being well boiled

in water soured with bran, and exposed to sunshine and air, in a few days became white in the parts where no mordant had been applied to fix and retain the colour, whilst the figures formed by the application of alumine, retained all their body and brightness; the colouring matter of the madder, in this triple combination, not being liable to destruction or separation by the same means which destroyed or separated it where no such bond of union or means of preservation existed.*

It has been already noticed, that in oriental calico-printing the solution of alum is coloured red with sampfan, or sappan wood; and I might have added, that in dying with chay root, the red colour of the wood is dislodged from the pores of cotton by the superior attraction of the root colour, which takes its place. Neither the East Indians, however, nor the writers who have given accounts of their operations, seem to have been apprised of this fact; but have concluded that the red wood colour was fixed, and made durable by applying that of the chay root.† To

* M. Berthollet, in the last edition of his Elements, &c. (tom. i. p. 80) has introduced my account of these experiments, to illustrate and prove the affinities of alumine employed as a basis, and also the different dispositions of colouring matters to be acted upon by these affinities.

† This erroneous opinion has been again very lately propagated in a French periodical work, of considerable respectability,

ascertain the truth on this point, I made several experiments, of which an account was given in my former edition; but they are now omitted, because those which I have since made with the *chay root itself*, and which will be stated hereafter, must render the former unnecessary.

After this account of the *acetate* of alumine, it is proper that I should notice *that* of iron, commonly called iron liquor, which, as employed in Europe, was manifestly borrowed from the Indians, with only the substitution of a vinegar from wine or malt, for that obtained by fermenting the juice of some of the different species of palm trees.

The means of producing an acetate of iron, obviously presented themselves, and did not require any more chemical knowledge, than people but very moderately civilized are commonly found to possess. Iron, in a state proper for being dissolved by vinegar, might be procured,

("Annales des Arts & Manufactures," No. 51,) where M. Le Goux de Flaix, in giving an account of the chay root, says, "This root is useful not to give colour, but only to fix that which has been otherwise given;" and he adds, that by not knowing this fact, it was found impossible to make any use of a large quantity of the chay root, imported by the French East-India Company to France, in the year 1774. The true cause, however, of the failure here mentioned, will be explained hereafter, when I shall have occasion to notice a similar failure, in regard to a recent importation into this country, by the English India Company.

without a previous decomposition for that particular purpose. But this was not the case with *alumine*, of which the nature was completely unknown, as well as the ways of procuring it; and even at this time, though we know it to be a particular and *pure species* of clay, we do not find it either practicable, or advantageous, to obtain it, except by separating it from the sulphuric acid, with which it has been previously dissolved, and combined in *common alum*.

The first European calico-printers, in making their iron liquor, employed many useless ingredients, as they also did in making the aluminous mordant. In the more early prescriptions I have found, besides old iron, and vinegar or sour beer, verdigrise, sugar of lead, blue vitriol, antimony, urine, the brine of pickled herrings, saltpetre, sal ammoniac, and other *incongruous* matters, frequently directed; and they were thought to be useful, because they did not *hinder* the oxide of iron from performing its office as a basis. Rye meal was for many years very commonly employed, and probably with some advantage. Afterwards, however, experience, directed by the light of chemistry, enabled the manufacturers and consumers of this mordant, gradually to discard the useless ingredients employed in making it, as they also did those which had for a considerable time encumbered, and in some degree injured the mordant, from alum.

Iron alone, dissolved by an acetous acid, then constituted the iron liquor; and to produce this acid, malt, or sour beer, or the *washings* of sugar hogsheads, were commonly employed, as being the most economical; and broken iron hoops, or other thin pieces of old iron, were subjected to the slow action of the acid. And when a more concentrated solution was wanted, either as the basis of very full adjective colours, or as a substantive topical colour, certain proportions of sulphate of iron were dissolved in the iron liquor, which, with or without this addition, always required to be thickened, like the aluminous mordant, when topically applied by the pencil, or printed by engraved blocks.

I scarcely need to add, that since the nature of pyroligneous acid was ascertained, this last has been preferred, as the cheapest, and in some respects most useful, for making the acetate of iron, as well as that of alumine.

When pieces of calico have been printed with iron liquor, whether it be applied to those which either have received, or are intended to receive, the aluminous mordant also, they are to be thoroughly dried by a *stove* heat, and afterwards passed through the mixture of cow-dung and warm water, in the manner directed for pieces which have been printed with the acetate of alumine only, and with a view to similar effects; and they are afterwards, in the language of the

calico-printers, to be *streamed*, or extended, in running water, and beat, to remove all the loose or uncombined particles of the mordant, and thus fit them to be dyed, with either madder, sumach weld, or quercitron bark; these being the principal, and almost the only adjective colouring matters so employed by calico-printers, and sufficient (excepting the blue from indigo) to produce, with the aluminous and ferruginous mordants, all the various colours seen and admired on printed calico.

E. G. If pieces of calico, to which these mordants have been applied, both separately and mixed, be put into a dying-vessel, with water scarcely blood-warm, and in which three, four, or five pounds of madder in powder, for each piece, have been previously mixed, and they be turned, as usual, through the liquor, by the winch; gradually, but slowly, raising the heat, so that it may only reach the boiling point at the time when the calicoes will have been sufficiently dyed, the several pieces will be found to have imbibed colour in every part. The figures or places to which the unmixed iron liquor was applied, will have been dyed black, and those on which the aluminous mordant was printed, will be red, of different shades, if the mordant had been used at different degrees of concentration; and, if both mordants were mixed and applied in different proportions, such applications will

have produced various shades of purple, violet, chocolate, and lilac colours; whilst the parts, or *grounds*, intended to be ultimately left white, will manifest a considerable brownish red discoloration: but as the madder colour producing it, is not then united to the calico, by the affinity or attraction of any intermediate basis, it will not be able, *as in other parts*, to resist the action of exterior agents, and may therefore (as is usually done) be removed, and the grounds made *white*, by boiling the pieces in water soured by fermented bran, and by afterwards spreading them for some days (according to the season) upon the grass; where, with the well-known treatment, the colours dyed upon *a basis* will become brighter, whilst that *without one* will completely disappear.

Calico, printed with the same mordants, and dyed with the quercitron bark, (quercus tinctoria, or quercus nigra, Linn.) will acquire fixed and bright yellows of different shades, upon the aluminous basis, and various drab colours upon that of iron. A mixture of these bases will produce olive colours. Along with these it is usual to produce black impressions at the same time, by previously applying to the calico a mordant composed of iron liquor and galls; by which figures, which, without the galls, would only have manifested a dark drab colour, are made *black*, by dying with the quercitron bark;

and if the dying be conducted as I shall hereafter direct, the grounds will be so little discoloured, that no exposure upon the grass will be required, as is necessary with madder and weld; an advantage which has nearly put an end to the use of weld in calico-printing.

This method, however, of *dying* yellow upon a *basis*, is an European invention; the people of India having only given it, as already mentioned, by a *pro-substantive* mixture of the decoction of the galls of myrobalans with alum. And, indeed, this practice was followed here for some time after the introduction of the art into Europe, excepting that, instead of the galls of the mirobalan tree, a decoction of French berries (rhamnus infectorius, Linn.) was employed; by which, indeed, a very full bright yellow was at first communicated, but of so *fugitive a nature*, that the use of these berries, which in some degree still subsists, ought to be discouraged; it being impossible, by any means yet known, to obtain from them a colour fit for any other purpose than that of deception.

Hitherto, the art of calico-printing has been confined almost solely to linens and cottons, which are suited to it, by being susceptible of a permanent union with colouring matters, and especially with their bases, by only the common warmth of the atmosphere: and as this is also the case of silk, there can be no doubt but this

last might be made the subject of new and beautiful embellishments in that way, which, if properly executed, would undoubtedly become a source of gratification to the public, and of profit to individuals.

Very lately indeed a species of topical dying or staining, very much resembling some parts of calico-printing, has been ingeniously applied to woollen stuffs, and particularly those called kerseymeres, for waistcoat patterns, &c. What I mentioned in a former chapter, of the necessity of a considerable degree of heat, to enable the fibres of wool to receive and combine with colouring matters, will afford some idea of the difficulty of applying and fixing different colours in the form of spots or figures upon woollen stuffs in this way by dying; the particular mode and means by which this difficulty is overcome, and the several colours fixed in the fibres of wool, are still kept secret as much as possible. How proper colours for this purpose may be provided, either from substantive colouring matters, or from the adjective ones, made into the form of a strong decoction, and mixed with the proper mordants, (as in the instance which I lately noticed of a pro-substantive yellow,) will be easily understood by those who may attend to what has been, or will be, explained in the course of this work; and such colours being so prepared, and printed upon kerseymere, &c. in

the usual ways, may be, as I have found on trial, and as I am informed they are, made to penetrate and unite with the wool, by placing the stuff so printed in the steam of boiling water for a sufficient length of time, first wrapping it up in thick paper, doubled or trebled, so as to exclude the moisture, so far at least as that it may not occasion the colours to run beyond their proper limits.

After this summary account of the origin, progress, and nature of calico-printing, intended to illustrate more distinctly the effects of the principal bases or mordants, it will be proper here to take a general view of the facts which respect the application of these bases, for fixing and modifying different adjective colours, not by topical, but by general dying, as well upon wool and silk, as on linen and cotton.

The two last of these, spun into thread or yarn, and either woven or not, are made fit for the application of a basis, by being boiled, for the space of three or four hours, in a solution or lye of pot-ash or of soda, of suitable strength; then spread for some time on the bleaching-ground; afterwards soaked in water, made sour by the addition of one-fiftieth, or sixtieth, of its weight of sulphuric acid, or oil of vitriol, and finally rinced thoroughly in clean water, and dried. When thus prepared, if the aluminous basis is intended to be applied to them, perhaps

there is no form in which it could be more effectual than that of the acetated aluminous mordant, though motives of economy have always induced the mere dyers of linen and cotton to employ cheaper preparations of that basis. The sulphate of alumine, or common alum, will indeed yield a part of its earthy basis to linen and cotton, when dissolved by water and applied to them; but it does this more readily when deprived of its excess of acid by pot-ash or calcareous earth; and it is in this way commonly employed as a mordant for linens and cottons. About four ounces of alum, with water sufficient to dissolve it, and half an ounce, or somewhat less, of pot-ash, are commonly allowed for each pound of linen or cotton intended to be dyed; and the latter are to be macerated, &c. in this liquor, cold, or only blood-warm, until thoroughly and equally penetrated by it, and afterwards well rinced, to separate the superfluous or loosely adhering alum, &c.* Cotton, treated in this way, commonly gains

* If, instead of the small proportion of pot-ash here mentioned, so much of it, or of soda in its stead, were employed, as would suffice first to precipitate, and afterwards re-dissolve, the alumine, the latter, being then in a triple combination with the acid and alkali, would be less attached to either, and more readily, as well as copiously separated, and united with the fibres of linen or cotton.

about two and a half per cent. additional weight by the alum, partly decomposed, which combines with it. But, where no white grounds are to be reserved, there are ways of separating the aluminous basis more advantageously, and applying it more efficaciously, particularly for madder colours upon linens and cottons, by impregnating them with oleaginous, astringent, glutinous, animal, and alkaline substances, which occasion an increased affinity or attraction between the fibres of the linen or cotton and the colouring matters; thereby forming, perhaps, a kind of cement, which renders them more fixed, and less liable to be acted upon and injured by those causes which generally destroy or weaken colours. These auxiliary means will hereafter be noticed in their proper places; and particularly when treating of the Turkey red.

Silk is to be impregnated with the aluminous basis, by macerating or soaking it only, during the space of ten or twelve hours, in a saturated cold solution of alum.

To impregnate wool or woollen cloth with the aluminous basis, it is commonly boiled in water, with from one-fourth to one-sixth of its weight of alum, and from one-twelfth to one-sixteenth of its weight of crude tartar, putting the latter first into the water, and, afterwards, the powdered alum: the heat of the water being

gradually raised, is kept at the boiling point for an hour and a half, or two hours, during which the cloth is turned through the boiling liquor on a winch, that the mordant may be equally applied; and being afterwards taken out and drained, it is commonly left until the next day, and then rinced in clean water, for dying. In the early collection of recipes, printed in 1605, and already mentioned, *sour bran* liquor is commonly directed to be employed in this way with alum; and it seems to have answered the purpose of tartar, which, when it came to be generally used in this way with alum, was supposed by the older dyers to do good by *softening* and *correcting* the acrimony of the latter: probably, however, the purposes which it answers, are not yet clearly ascertained; one of them seems to be, that of increasing the solubility of alum, and enabling it more completely and intimately to penetrate the fibres of the wool, with which it moreover enters into a permanent union, and thereby contributes efficaciously to modify, vary, and in some cases to brighten the colours with which it is employed, as will be seen hereafter.

It was until very lately believed, even by those who had most knowledge of the subject, that woollen cloth boiled in this way, with alum, decomposed the latter, in a considerable degree at least, attaching to itself the alumine,

though not without a small portion of the sulphuric acid in combination therewith.* Very recently, however, MM. Thenard and Roard (of whom, the latter is director of the dying department at the imperial manufactory of the Gobelins at Paris,) appear to have acquired more correct ideas on this point, by a series of experiments, of which they have given a minute statement, in a memoir read at the Physical and Mathematical class of the French National Institute, (see Ann. de Chimie, tom. 74, p. 267.)

These experiments were principally made with alum, acetate of alumine, tartar, and the solutions of tin, applied to wool, silk, and cotton; and by these, it was fully ascertained, that alum and cream of tartar do not decompose each other when dissolved in water, and boiled with wool, (a fact which had, indeed, been previously asserted by Berthollet); that in this boiling, the wool combines with the alum, *without decomposing it in any degree*,† and also with the tar-

* Berthollet, tom. i. p. 80, after saying, that in aluming stuffs the latter decompose the alum, and combine with the alumine, whilst the acid which held it dissolved, separates and remains in the bath, adds, " Mais il ne faudrait pas conclure de là, qu'aucune portion de l'acide ne reste dans la combinaison de l'étoffe où elle peut avoir quelque influence sur la couleur."

† It was completely ascertained, that when wool had been so *alumed*, the alum employed might be all recovered, partly from the bath or liquor in which the aluming had been per-

tar; that equal parts of alum and tartar would dissolve in two-fifths *less* of water, than would be required to dissolve them separately.

They found that wool, as it is commonly *cleansed* for being *alumed*, was not deprived of the carbonate of lime naturally combined with it; and that this wool, being boiled the usual time, with one-fourth of its weight of alum, and one-sixteenth of its weight of cream of tartar, rendered the bath, or water, troubled or muddy, and produced (as is, indeed, commonly observed) a copious white sediment, which being collected, washed, and analysed, was found

formed, and partly from the wool itself, by repeatedly washing the latter in pure boiling water: commonly a dozen separate washings were sufficient to remove completely all the alum which had united itself to the wool; and the alum, so separated, was susceptible of a distinct crystallization, as if it had never been so employed. After the last of these washings, the wool or cloth, so washed, was found to be as incapable of receiving colours by dying, as if it had not been alumed; and, indeed, *before the last*, it was always found, that the colour attempted to be dyed upon it, was feeble, in proportion to the number of washings which had taken place.

It became evident, therefore, from these experiments, that wool or cloth boiled with alum (and tartar) attached to itself the *undecomposed alum only*, and that a decomposition of the latter does not take place until the subsequent operation of dying, when the affinity of wool, being assisted in the dying vessel, by the affinity of the adjective colouring matter, their *co-operation* separates the alumine, in a great degree at least, from the sulphuric acid.

to consist chiefly of a sulphate of lime, and a saturated sulphate of alumine. That when wool had been properly cleansed, and deprived of its carbonate of lime, no sulphate thereof was found. Such wool or cloth, being boiled in pure distilled water, with the proportions just mentioned of alum and tartar, and the bath or liquor with which the boiling had been performed being carefully evaporated, a residuum was found, consisting of alum, cream of tartar, and a compound, difficultly crystallizable, of tartrite of pot-ash and animal matter. The wool itself, when so boiled, afforded, by repeated washings, alum, and a small quantity of cream of tartar, besides a very sour combination of tartaric acid, alum, and animal matter. As the acid of tartar combines so copiously with wool, MM. Thenard and Roard have inferred, that it ought not to be employed in this way with alum, except for colours which acids contribute to raise and improve: and among such colours they rank those of cochineal, kermes, and madder; but those of weld, logwood, and Brasil wood, not resisting acids as they suppose, wool, intended to be dyed from either of these, ought, as they think, to be alumed, without any addition of tartar. The accuracy of these opinions will be tried by facts, when the several colouring matters here mentioned shall claim our particular attention.

These gentlemen did not find any advantage to arise by a prolongation of the boiling with alum and tartar beyond the space of two hours, nor by increasing the proportions of alum and tartar; but, on the contrary, thought they observed beneficial effects from a diminution of them with weld, logwood, and Brasil wood, but not with cochineal, madder, or kermes. Nor did they find any benefit produced, by letting the wool or cloth remain some days in the liquor with which it had been boiled, as some persons have advised.

From these experiments, MM. Thenard and Roard have thoght themselves entitled to conclude, with "*certitude*, que dans l'alunage de toutes les matières animales, l'alun *se combine en entier* avec elles, sans éprouver aucune décomposition, et qu'il forme alors des combinaisons plus ou moins solubles, qui ont pour les matières colorantes une grande affinité;" and they have made a similar conclusion in regard to vegetable matters, (i. e. linen and cotton, &c.); having found that the latter, when carefully alumed, might be completely deprived of every particle of alum, by fewer washings than silk, and by *much* fewer than wool, which had been so alumed. They found also that, (as with *silk*,*

* Silk ought never to be subjected to a *boiling* heat, either when the mordant is applied, or afterwards, in the dying opera-

and for similar reasons) it was always best to begin the dying of linen and cotton (when alumed) at a low temperature, and to keep the dying liquor considerably below the boiling point, until the colouring matters were enabled to attach themselves to the mordant, and produce an insoluble combination therewith, previously to its being subjected to the action of *boiling* water.

These gentlemen, moreover, ascertained, that when acetate of alumine was applied to wool, silk, linen, and cotton, it combined with them entirely, undecomposed, like alum; but, being exposed to a warm atmosphere, a part of the acetic acid, from its volatility, soon evaporated, leaving behind an *excess of alumine*, which could not, like the mere acidulated acetate of alumine, be carried off by boiling water: a fact which accords with the explanation lately given of the utility of this mordant in calico-printing.

In regard to the solutions of tin, it appears, that woollen cloth, boiled with them in water, and the proportion of tartar which is commonly employed in dying scarlet, combined with the acids, as well as with the oxide of that metal;

tion; where a high temperature, besides injuring the texture and lustre of the silk, would detach and separate the mordant, before the colouring matter could have combined and produced an insoluble union with both.

and that by numerous washings afterwards with distilled water, boiling hot, all these matters were completely separated; and that, by evaporating the washings, they were collected in the form of tartaric acid, and muriatic acid, combined with tin; while the mother water contained (as was also ascertained by evaporating it) tartrite of pot-ash, acidulated tartrite, and a very acid muriate of tin. It results, therefore, from these experiments, that wool has no more power to decompose the solutions of tin, than it has to decompose those of alum; and that, when not assisted by the affinity of some colouring matter, it unites with both the tin and the acids, holding them in solution.

The different solutions of tin, the best means and methods of producing them, and their respective effects in dying, will be noticed hereafter; and more especially when I come to treat of the dying of scarlet with cochineal, for which that metal was first employed as a mordant, and with advantages so remarkable, that the discovery of its use for that purpose, may be considered as an important æra in the history of this art.

The mordants afforded by iron, when employed upon wool and silk, are commonly applied either subsequently to, or interchangeably with the colouring matters intended to be fixed or modified by that basis, as will be more parti-

cularly explained, when the dying of black claims our attention.

It will be ascertained hereafter, by my own particular experiments, that all the metals, properly so called, as far as they have been tried, are capable of attracting adjective colouring matters in some degree, and of serving as bases to them; and this is also true of most of the earths; though none of them is so efficacious and useful in this way as alumine; indeed this, and the oxide of tin, seem to be the only bases suited, by their perfect *whiteness*, to reflect the rays of light so as to exhibit adjective colours with their utmost lustre and brightness, every other falling short of these in that respect, and almost all of them appearing to sadden or darken the colours which they serve to fix. Probably, the oxides of zinc and antimony do this less than any of the others: the former, however, (zinc) does not appear, by my experiments, capable of giving *much* stability and permanency to *any* colour dyed with it.

After this *general* explanation and illustration of the properties and uses of mordants or bases in fixing and modifying adjective colours, I shall next proceed to a *particular* inquiry concerning their effects upon *each* of the more important dying drugs of this class, beginning with those which belong to the *animal* kingdom.

CHAP. II.

Of Adjective Colours from European Insects, and principally from the Kermes, *or Coccus Ilicis, Linn.*

"La laine et la soie qui montreroient plutôt dans leur couleur naturelle la rusticité de l'age, que l'esprit de l'homme et la politesse du siècle, n'auroient qu'un médiocre commerce, si la teinture ne leur donnoit des agrémens qui les font rechercher et desirer, même par les nations les plus barbares."

Colbert, *Instruction générale pour la Teinture, &c.* 1672.

Among *animal adjective* colours, the *kermes* are entitled to our *first* notice, because they appear to have been used for dying at a very early period; and, like the murex and buccinum, were probably first employed for that purpose by the *Phœnicians*. Being unacquainted with the oriental languages, I can only adduce to this point the opinions of others, better qualified than myself in that respect. One of these is Professor Tychsen, (quoted by Professor Beckman, vol. ii. p. 185 of the English translation of his History of Inventions,) who says, that among the Hebrews, the kermes dye was mentioned, under the names of "*tola schani*, or simply *tola*, by their oldest writer, Moses;" that "*tola* is properly the *worm*," and that "the addi-

tional word *schani*, signifies either double dyed, or, according to another derivation, bright, deep, red dye;" that for the shell "purple, the orientals have a particular name, *argaman*, or *argevan*, which is accurately distinguished from *tola*;"—"all the ancients, therefore, translate the Hebrew word *tola*, by κοκκος, kermes, zehori, and zehorito, (deep red, bright dye.) which words they never put for argaman." After these and other observations, he concludes, that "the scarlet, or kermes dye was known in the East, in the earliest ages before Moses; and was a discovery of Phœnicians in Palestine, but certainly not of the small wandering Hebrew tribes." That "tola was the ancient Phœnician name used by the Hebrews, and even by the Syrians; for it is employed by the Syrian translator, Isaiah, chap. i. v. 18."—"Among the Jews, after their captivity, the *Aramæan* word *zehori* was more common."

Bischoff also maintains, that the kermes red dye was meant by the Hebrew words tholaat schani, in several parts of the Old Testament. It may, therefore, be assumed, that the colour which is mentioned in Exodus, chapters xxvi. xxviii. and xxxix. (as one of the *three* which were prescribed for the curtains of the tabernacle, and for the "holy garments" for Aaron,) and which the English translators have rendered by the word *scarlet*, (as they have done

in other parts of the Old Testament) was no other than the blood-red colour, dyed from the kermes. Indeed, the colour now denominated scarlet, and dyed from *cochineal*, upon a *tin basis*, had not been discovered when the last English version of the Bible was made, in the reign of James the First.

The Greeks appear to have obtained a knowledge of the kermes, and their use in dying, at a much later period; and we find this insect denominated κοκκος βαφικη by Dioscorides, iv. 48, p. 260, and by other Greek writers: whence the Latins derived their names of *coccum* or or coccus, with the addition of infectoris, or infectorium. Pliny, as I have noticed at p. 125, mentions the kermes as being sometimes employed, conjointly with the colour of the murex and buccinum, in producing a sort of purplish crimson, called by the Romans *hysginus*. He adds, upon that occasion, that this drug was brought from Galatia, or from the vicinity of Emerita, in Portugal, and that the *latter* was the most commended.* And again, in his xvith book, chapter viii., after describing various uses or products of the oak, he mentions the coccum, or kermes, as being the most excellent; adding, that it is an excrescence, produced upon

* "*Coccum* Galatiæ *rubens granum*,"—"aut circa Emeritam Lusitaniæ, in maxima laude est." Plin. Hist. lib. ix. c. 41.

the stems of a small shrub, called the *ilex* aquifolia;—but of such value, that the people of Spain are enabled to discharge half their tribute by it; and that it is also produced in Galatia, Africa, Pisidia, &c. Lastly, Pliny, in the second chapter of his twenty-second book, after noticing the great improvements which had been then recently made in the art of dying, mentions (while he professes to pass over) the grains brought from Galatia, Africa, and Portugal, and *appropriated for dying the imperial robes*, &c.*

The ancients had but very incorrect notions of the kermes, many supposing them to be the grains or fruit of the ilex. They saw, indeed, that insects were ultimately evolved or produced from them; but believing, as they did, that insects might be spontaneously generated by corruption, this evolution did not appear incompatible with their supposition, that the kermes was properly the grain, or berry, of the tree on which it was found.

From the name of coccum or coccus, cloth dyed red with kermes was designated by the substantive coccinum, and the adjective coccinus, or coccineus;† and persons wearing such cloth

* "Atque ut sileamus, Galatiæ, Africæ, Lusitaniæ granis, coccum *imperatoriis* dicatum paludamentis," &c.

† Corresponding designations were given in the original Greek, as well as in the Latin version of St. Matthew, xxvii.

were said to be *coccinati*, according to the following line of Martial, viz.

"Qui *coccinatos* non putat viros esse."

It will have been seen, by the passages which I have recently quoted from Pliny, that the appellation of *granum* was given by him to the kermes insect, doubtless, from its resemblance to a grain or berry; and this appellation has been continued by succeeding writers,* and, doubtless, occasioned the colours dyed from the kermes to be called *grain*, or *ingrain* colours, as those of cochineal afterwards were, from a similar mistake, which for some time subsisted, concerning the nature of that insect.

By a succession of observations, however, it seems to have been ultimately ascertained, that the worm or insect was the most important part of the supposed grain or berry in producing the kermes red, and, therefore, in what have

v. 28, to the *robe* which our translators denominate *scarlet*, and with which the soldiers clothed and derided *Jesus*, when, having "platted a crown of thorns, they put it upon his head, and a reed in his right hand, and they bowed the knee before him, and mocked him, saying, Hail, King of the Jews." The fact shews, that the kermes red was then considered as an attribute of *royalty*.

* In modern times, the kermes have been called by the Italians, *grana da tintore*; by the Spaniards, *grana de tinctores*; by the French, *graine d'escarlate*; and by the English, kermes *berries*.

been called the middle ages, this production was frequently denominated *vermiculus*, or *vermiculum*, and the cloth dyed with it vermiculata; and hence ultimately originated the French word *vermeil*, and that of *vermilion* derived from it.

The Spaniards, and through them the other nations of Europe, appear to have obtained the name of *kermes* from the Arabians, who, according to their own accounts, were made acquainted with it, as well as the substance, by the Armenians* and Persians, among whom

* Beckman says, that J. Beithar, in Bochart *Hierozoicon*, ii. p. 625, calls kermes an Armenian dye; and that the Arabian lexicographers, from whom Giggeus and Castellus made extracts, explain the kindred word *karmasal*, (coccineus seu vermiculatus) as an *Armenian* word. It is notorious that the insects in question have long been produced and employed for dying, both in Armenia and Persia; and that they were there called *kermes*, may be proved among other testimonies by the following extract from Sir John Chardin's account of Persia, published in Harris's Collection of Voyages, where, treating of *Media*, he says, "they gather cochineal, though in no great quantity, nor for any longer time than eight days in summer, when the sun is in Leo; for before that time the people say it doth not come to maturity; and after it, the *worm* from which they draw the cochineal, makes a hole in the leaf in which it grows, and is lost. The Persians (he adds) call cochineal *kermes* from *kerm*, which signifies a *worm*, because it is extracted out of worms." It can hardly be necessary to remark, that the term cochineal is here improperly used, and that nothing more is meant by it, than the colouring matter of the kermes;

(as has been mentioned by Dioscorides, Dodoneus, and others) kermes was an indigenous production, and had for many ages been employed in dying. By thus adopting the name of kermes, the Italians afterwards produced from it the words *chermisi*, *cremesino*, and *chermesino* ; and the French those of carmesin, carmine, and cramoisi ; whence the English word crimson was borrowed.

The origin or derivation of the name escarlatum, scarletum, scarlata, squarlata, scarlatina, or scharlatica, from which the French escarlate or écarlate, and the English *scarlet* have been formed, is more uncertain : Pezronius thought it of Celtic extraction ; and that it signified *galaticus rubor*. (see Antiq. Celt. p. 69.) But according to Beckman, *Stiler* asserts that *scarlach* is a German word, compounded of *schor*, fire, and *lacken*, cloth ; and consequently that it signifies *fire-coloured cloth* : while Reiske, on the contrary, derives the words in question from the Arabic *scharal* meaning, the kermes dye.

It may be observed in favour of Stiler's assertion, that the kermes red has in different ages been compared to the *colour of fire*. I have seen the words " *ardenti* radiabat Scipio *cocco*."

which continues, according to the best information that I can procure, to be employed in a great part of India, as well as Persia, particularly for the dying of silk.

in some of the Latin classics, though I cannot recollect which. And Bischoff, on the authority of Muratori,* mentions an old charter or contract passed in the year 1194, between the cities of Bologna and Ferrara, by which a duty was to be levied in the former of these cities, upon the grana de *Brasile*, meaning kermes, (and upon indigo); and he adds that these Brasilian grains, and also Brasil wood, are mentioned in other old charters, particularly one dated in 1198, and another in 1806, under the name of *Braxilis*; and he concludes, with great probability, that this, and the word *brasilis*, were derived from *bragio* a *burning coal;* in the French *braise:* and we shall accordingly find hereafter, that *red* dying woods, similar to that now called *Brasil* wood, were distinguished by that name, before any such wood was known or suspected to be produced in that part of America now called Brasil; and that this name was given to that country many years afterwards, when the wood came to be thence imported; and consequently that the country obtained the name from the wood, and not the wood from the country.

At what time the words from which our scarlet was derived were first used, cannot, I believe, now be accurately ascertained; the

* Dissert. de Mercatibus et Mercatura sæculorum rudium, tom. ii—Antiquitat. diss. xxx, p. 898.

most early employment of them, of which I have found an instance, is that which Beckman has quoted from the Historia Gelrica Pontani, (Hordervici 1639,) in which, about the year 1050, the emperor Henry III. conferred upon the Count of Cleves, the Burgraviate of Nimeguen, on the condition of his delivering to him annually three pieces of scarlet cloth, made of English wool ("tres pannos *scarlatinos anglicanos.*") Beckman also refers to a document in Lunig's Codex Diplom. Germaniæ, ii. p. 1739, by which the emperor Frederick, in 1217, conferred on the Count of Gueldres, the hereditable jurisdiction of Nimeguen, on condition that he and his successors, "de eodem telonio, singulis annis tres pannos *scarlacos* bene rúbeos anglicenses *ardentis* coloris assignare deberet." The selection of English cloth, in these instances, demonstrates the high estimation in which it was held even at those periods. Beckman also refers to "Gervasii Tilberiensis Otia Imperialia ad Ottonem iv. Imperatorem, iii. 55;" a work written in 1211, in which the author alluding to the kermes says, "Vermiculus hic est, quo tinguntur pretiosissimi regum panni, sive serici, ut examiti, sive lanei, ut *scharlata.*" And he then mentions it as wonderful that neither linen, nor any other vegetable substance, would permanently take this dye, "sed sola vestis quæ ex vivo animanteque, vel quo vis animato decerpitur." He

afterwards mentions the shrub on which the kermes were found, and, like Dioscorides, compares the latter to *peas*, in regard to their shape and size; adding, "cum enim tempus solstitii æstivi advenerit, ex seipso vermiculos generat, et nisi coriis subtiliter consutis includerentur, omnes fugerent, aut in nihilum evanescerent. Hinc est quod vermiculus nominatur, propter dissolutionem quam in vermes facile facit, ex natura *roris maialis, a quo generatur;* unde et illo tantum mense colligitur." We see by the latter part of this extract, that the kermes were not at that time, as at present in France and Spain, *killed* by being sprinkled with vinegar and dried in the sun; and therefore, to prevent their ultimate escape, they were secured by being put into leathern bottles.

Besides these instances of the early mention of scarlet, it occurs in several books, written in the thirteenth century; such as the History of Spain, by Roderick archbishop of Toledo, (lib. vii, 1), which was finished in 1243; and in some quoted by Vossius, "de vitiis sermonis, 4°." Others might be added to these, were they necessary.

At the periods when the terms escarlatum, &c. were thus employed, the art of dying *purple* from the murex and buccinum was lost in the western empire, and the kermes dye, which in former times had been almost as much esteemed,

was become pre-eminent and unrivalled; and so it continued, until the introduction of cochineal, from America, (to be noticed in my next chapter) which has, in great degree, put an end to the use of kermes in Europe, though the acorn-bearing shrub, which the ancients called ilex, (and which, in the Linnæan system, is denominated quercus coccifera) still grows, and furnishes these insects, in all the countries mentioned as formerly producing them; and though the insects themselves continue to be employed in other parts of the world, and with great reason, for in truth they are capable, as my own experiments prove, of giving every colour which can be obtained from cochineal with equal beauty and vivacity, and perhaps with even greater permanency.

The first volume of the Philosophical Transactions contains a paper, written by M. Verney, then of Montpellier, respecting the natural history of the kermes; and M. Reaumur afterwards described them very minutely in the fourth volume of his "Mémoires pour servir à l'Histoire des Insectes." But the most useful information on this subject seems to be that which M. Chaptal lately gave to M. Berthollet, and which he has published in the second volume of his "Elémens de l'Art de la Teinture." By his account, the male insect passes from its vermicular state, through the usual forms, into that

of a fly with four wings; though the female never acquires any wings, but fixes herself on a leaf of the oak, where, being impregnated by the male, her size gradually increases (as the eggs enlarge) to that of a juniper-berry, and she at the same time becomes of a reddish brown colour. When the eggs are on the point of hatching, the females should be collected, and exposed to the steam of vinegar, to kill them, and prevent their young from being brought forth; and afterwards they should be dried, by being spread out on cloths, by which treatment they acquire the colour of red wine. M. Chaptal says, that a single person may collect from one to two pounds of kermes in a day. But it would require ten or twelve pounds to produce the effect of a single pound of cochineal; and as the kermes, probably, could not be obtained in any quantity for less than half-a-crown the pound, the colour which they afford, would prove more costly than that of cochineal, at the price which the latter has commonly borne previous to the present war.

Hellot tells us, chapter xii. that the red draperies of the figures exhibited in the ancient Brussels and other Flemish tapestries, were all dyed from kermes, and that this colour, which in many of them has subsisted more than 200 years, has lost but very little, if any, of its original vivacity: and Beckman represents this

as being true of some pieces of tapestry, which are believed to have been dyed with kermes as early as the twelfth century. The fine red or crimson colour of these tapestries, which was originally called simply scarlet, took the name of *Venetian* scarlet, after the cochineal scarlet upon a tin basis was discovered, because, as Hellot mentions, it continued to be extensively dyed at Venice, long after it had become unfashionable in other parts of Europe; though it appears, from my own particular experiments, that if the kermes, like the cochineal, had been employed with a solution of tin by nitro-muriatic acid (instead of alum), a colour might have been obtained, which it would have been difficult, if not impossible, to distinguish from the cochineal scarlet.

To dye the Venetian scarlet, the wool, according to Hellot, was first boiled for half an hour in water, with about its weight of bran, tied up in a bag; it was then removed into another vessel, and boiled two hours in water acidulated by fermented bran liquor, with a fifth of its weight of Roman alum, and half as much red tartar; leaving the wool, after taking it out of this vessel, moistened with the same liquor, during six days; at the end of which, it was dyed in clean soft water, with powdered kermes, allowing twelve ounces of the latter for

each pound of wool, and even sixteen ounces, if the kermes had suffered by age.*

When the very extraordinary effect of a solution of tin, in giving vivacity and lustre to the colour of cochineal, had been discovered, (as will be mentioned hereafter) it might have been expected, that the influence of this mordant upon the kermes colour would have been tried, as a matter of course, but I cannot any where find that this was done; and it was not until I had dyed broad-cloth in the way, and with the means commonly employed to produce the scarlet colour, substituting only kermes for cochineal, in the proportion of twelve ounces of the former for one of the latter, that I satisfied myself of the practicability of dying with the kermes a scarlet colour, in every respect as beautiful and estimable as any which can be dyed

* In a letter written by Mr. William Kirkpatrick to Dr. Anderson, lately Physician-General in the service of the East-India Company, and dated *Hyderabad*, June 14th, 1796, I find the following passage, viz. "The silk-dyers at this place do not know how, I believe, to produce a scarlet. To dye a prime crimson, they employ, to one seer of silk (fresh and white) one quarter seer of kermes, one quarter seer of alum, and one quarter seer of flowers of pisteh (pistachio), which I take to stand in place of the gall. The enclosed is a specimen of their prime crimson." If this account of proportions be accurate, the kermes of India must yield more than twice as much colour as that of Europe.

with cochineal; and, consequently, that if the mordant from tin had been properly employed with the kermes, there could have been no reasonable motive for giving a preference to cochineal, unless it was found to be ultimately cheaper than the kermes, by reason of the much greater proportion of colouring matter afforded by it.

Cotton being topically impregnated with the acetate of alumine, as for calico-printing, and one-half of it being dyed with kermes, it took a full bright crimson, as the other did at the same time with cochineal; and the colours so dyed, (which in appearance were exactly similar) being washed and exposed to the sun and air, manifested a considerable degree of permanency, though not sufficient to make it proper to employ them in this way, without an addition of madder; the yellowish red colour of which is greatly improved by the bright crimson of either of these insects. I have thought, in this and other experiments, that the colour of the kermes was a little more durable than that of the cochineal, not from a difference in the colouring matters of the insects, but from the *astringent* vegetable matter, or juice of the oak, which always accompanies the kermes.

Subsequently to my former edition, I procured a very sufficient supply of kermes from the South of France, and have tried them with

nearly all the metallic and earthy bases or mordants, and always with very nearly the same results as were obtained with the like bases or mordants from cochineal, and of which an account will be given hereafter; and I conclude, therefore, that the animal part of the colour of the kermes is *exactly similar* to the colour of cochineal.

Art. II. *Coccus Polonicus*,

This is a small round insect, in many respects similar to the kermes, and employed for nearly the same purposes, until the introduction of cochineal caused the use of it to be abandoned, at least in the greater part of Europe. It was mostly collected in the Ukraine, and other provinces of Poland, (under the name of *Czerwiec*) and also in the great duchy of Lithuania, from the roots of the German knot grass, or perennial knawel (scleranthus perennis, Linn.). The male only, by a transformation similar to that of the male kermes, becomes a fly, though with but two wings, which are white, edged with red. The females being impregnated by the male, enlarge their size, and become ready to bring forth their young soon after the summer solstice, at which time they abound most in a crimson juice, which even now is much esteemed and employed by the Turks and Armenians for dying wool, silk, and hair, and also to stain the nails of women's fingers. Wool and

silk were prepared to receive this dye with the same mordant (of alum and tartar) as that used for the kermes. Several writers have mentioned the coccus polonicus (sometimes called the cochineal of the north): but the best account of it seems to be that given by Breynius in the Act. Natur. Curiosor. of the year 1733. There is also an account of it in the Phil. Trans. for 1764, p. 91. Some writers have imagined, that the Latin, Italian, and French words signifying *crimson*, were more particularly applied to the colour dyed from the coccus polonicus; but I do not find sufficient reason for adopting that opinion.

Very similar to the coccus polonicus is an insect, which in many parts of Europe was formerly collected from the roots of the Burnet, (poterium sangui sorba, Linn.); and which was used, particularly by the Moors, for dying wool and silk of a rose colour. Ray, in describing this plant, says, "Hujus radicis adnascitur quibusdam in locis *granum rubrum*, quo utuntur tinctores ad colorem *carmesinum*, unde sunt qui pro cocco habent, et coccum radicum appellant," &c. Hist. Plantar. 401.

The coccus uvæ ursi, Linn., is another insect of the same order, and very much resembling the coccus polonicus, both in its properties and form, excepting the circumstance of its being nearly twice as large. It affords a crimson dye with alum, but is now seldom employed.

CHAP. III.

Of the Natural History of Cochineal.

> " Our vallies yield not, or but sparing yield
> " The dyers' gay materials. Only weld,
> " Or root of madder, here, or purple woad,
> " By which our naked ancestors obscur'd
> " Their hardy limbs, inwrought with mystic forms,
> " Like Egypt's obelisks."
>
> DYER.

THE cochineal, or coccus cacti of Linnæus, is arranged among the "Insecta" of the fifth class of that great naturalist; and in the second order, comprehending the "Hemiptera," (half-winged insects, &c.) The body of the male is slender, of a red colour, covered by two wings, spread horizontally, and crossing each other a little on the back, and enabling him to fly, or rather flutter. The head is distinct, but small, with two diverging slender antennæ; the abdomen or tail is terminated by two small and very long diverging hairs; he has six feet, with which he sometimes jumps, like the lacca insect; and hence Linnæus has applied the term "saltatoria," as one of his distinguishing characters. The male insects are but seldom found among the cochineal sent to Europe. The back of the female is hemispherical, and crossed by

numerous wrinkles; she is of a dark reddish brown colour; her mouth is a small tubular projection from the thorax; she is without wings, but has six legs; these, however, only serve her to remove during a short interval immediately succeeding her birth; after which they become useless, and ceasing to grow, whilst the body enlarges greatly, they, with the proboscis and antennæ, remain so small as to be afterwards hardly perceptible, at least without a very minute inspection. This circumstance probably occasioned, and certainly confirmed, the belief which prevailed very generally in Europe, during a considerable number of years, that these insects were vegetable grains or seeds.*

* Caneparius was deceived in this way. He had been informed, that the cochineal consisted of insects collected from plants of the cactus kind by the help of forceps, and smothered; but he considered this as fabulous, asserting that the cochineal, which he calls "*kabasinii grana*," if steeped in hot water, recovered their *original form*, which, adds he, is not that of any thing animalcular, but distinctly the figure of a seed or grain of some fruit. "Non est ullius animalunculi, at seminis sive grani fructus figuram refert. Quare hæc grana sunt ficus Indicæ rubra et splendida ut sanguis." He had heard that the fruit of the cactus "*Tunæ*," or Indian fig, was red, and that it tinged the urine of those eating it, of a blood colour, which encouraged him to conclude as he did, that cochineal must be the seeds "*ipsius tunæ*;"—"pro colore, *carbisino* vulgo *chremise* conficiendo tinctoribus commodo." See Caneparius, De Atramentis, &c. Venice, 1619. p. 211, 212.

The cochineal is nourished, perhaps exclusively, by some of the different species of the *cactus,* or Indian fig, (called by some the prickly pear,) a genus of plants, of which twenty-eight several species have been described, all originally found in America only; of very different forms, and producing fruits of various colours when ripe, according to the species on which they respectively grow; as yellow, red, crimson, purple, violet, green, &c. Among these, the red or crimson-coloured fruits more especially contain a mucilaginous juice, which communicates the colour of the fruit in a high degree to the urine of those by whom it is eaten. That species on which the domesticated cochineal has been commonly propagated, is denominated cactus cochenillifer or coccinilifer by Linnæus. But the insects live naturally, in their wild state at least, on some of the other species, particularly the cactus tuna, cactus opuntia, and cactus pereskia; all of which, as well as the cactus cochenillifer, belong to that section of cacti which Linnæus distinguishes as "opuntiæ compressæ, articulis proliferis," *i. e.* flattened or compressed with prolific articulations. The cactus cochenillifer, however, which the Mexican Spaniards call nopal, is alone cultivated for the purpose of feeding and breeding these insects; partly because it is unarmed, or

without those offensive spines which beset most of the other species.

The Spaniards, on their first arrival in Mexico, about the year 1518, saw the cochineal employed, (as it appears to have been long before,) by the native inhabitants of that country, in colouring some parts of their habitations, ornaments, &c. and in staining their cotton; and being struck with its beautiful colour, some accounts of it were given to the Spanish ministry, who in the year 1523, (as Herrara informs us) ordered Cortes to take measures for multiplying this valuable commodity;* but as the Spaniards then in America were careless of every thing but gold and silver, they left this to be done by the natives, who, from the large supplies soon after sent to Europe, appear to have successfully employed themselves for that purpose.

* Herrara does not use the name of cochineal, but that of *grana*, (as other Spanish writers have since done); and he says, (Decade, iii. v. 3.) the Catholic King had been informed that these *grana* were abundant in that part of America, and that the sending them to Spain might furnish means for paying the *contributions*, &c:—they were probably then supposed to resemble kermes. I have not been able to ascertain the origin of the term cochineal, or coccinilla, nor the time when it was first applied to these insects: perhaps, as they were smaller than the kermes, the term coccinilla was intended as a diminutive of *coccum*, as platina was of Plata, and both employed from similar motives; perhaps, also, it may have been erroneously supposed to belong to the genus coccinilla, or lady-bird.

It is remarkable, that though Acosta had stated the cochineal to be an insect, as early as 1530, and though Herrara and Hernandez did the same afterwards, these opinions were generally overlooked or disregarded, and the people of Europe were for many years induced to believe, that this insect was a vegetable grain or seed, as I lately mentioned; a contrary opinion was, indeed, given by the anonymous author of a paper, in the third volume of the Philosophical Transactions, (printed in the year 1668,) in which he supposes cochineal to be an insect, "*engendered*" by the fruit of the prickly pear; and being a believer of equivocal generation, he proposes to employ fermentation as a means of engendering and multiplying these insects more copiously.

In the year 1672, a paper written by Lister, was published in the seventh volume of the Philosophical Transactions, concerning the kermes, in which he "conjectures cochineal may be a sort of kermes." And the seventeenth volume of the Transactions, published in 1691, contains some observations concerning the making of cochineal according to a relation had from an old Spaniard at Jamaica, who says, "Cochineal is the same which we call lady-bird, alias cow-lady,*

* The lady-bird, or cow-lady, has long been distinguished by the generic name of *coccinella*; a fact which may have occa-

which at first appears like a small blister, or little knob upon the leaves of the shrub on which they breed, and which afterwards, by the heat of the sun, becomes a live insect as above, or a small grub."

Early in 1693, Father Plumier wrote and subscribed a declaration, which he delivered to Pomet, affirming cochineal to be an insect living on the opuntia or Indian fig, and that he had seen it in the island of St. Domingo; and De Laet had some little time before described it as feeding on the tuna. Pomet, however, misled by the prevailing opinion on this subject, as well as by several letters which about that time were sent to him from St. Domingo by F. Rousseau, adopted the fallacious accounts of this letter-writer, (who promised to send over to France some of the very plants whose seeds, as he asserted, afforded the true cochineal,) and described this drug as the seed of a plant, two or three feet high, bearing pods of a conical form, in which the cochineal grew naturally. (See Hist. Gen. des Drogues, &c.)

But, groundless as this account was in reality, it obtained so much credit, that no longer than

sioned several mistakes. It seems to have misled Professor Fischer, when, in 1758, he proposed to propagate the lady bird or fly, by placing it on the kermes oak, and the perennial knawel, in order to produce cochineal in Europe.

four years since, a very eminent dyer of this metropolis seriously told me, that having bought a large parcel of cochineal, he actually found among it one of these conical pods, containing cochineal naturally attached to the inside of the pods.

Lewenhoek, however, by his glasses plainly saw, that the cochineal was an insect with six legs; and in a letter, read at the Royal Society the 21st of March, 1704, and published in the xxivth volume of the Transactions, he positively contradicted all those who had represented it as a vegetable grain; and declared that, by dissections, he had invariably found eggs, or animalcula, in the supposed grains, and often to the amount of two hundred in each. He also represents these insects as "not produced from worms," but as "at once bringing forth their like."

About the year 1730, Dr. Rutty, then Secretary of the Royal Society, published a Natural History of Cochineal, (in the xxxvith volume of the Transactions,) from a work on this subject by Melchior de la Ruuscher, of Amsterdam, who had procured from Antiquera, in New Spain, the depositions of eight persons, who had been actually employed for many years in the breeding and management of cochineal, and who swore that they were small living animals with "a beak, eyes, feet," &c. and the originals of

these depositions, notarially authenticated, were deposited in the archives of the Royal Society.* Not long after this, Reaumur, in his Hist. des Insectes, and Dr. Brown, in his History of Jamaica, described the female cochineal with sufficient accuracy; as did Linnæus some time after, from some which had been sent to him by Rolander from Surinam, in the year 1756;† though neither of these naturalists had ever seen the male cochineal.

About the beginning of the year 1757, the late John Ellis, Esq. F. R. S. hearing that the cochineal insect bred in great abundance on the cactus opuntia, in South Carolina and Georgia, wrote to Dr. Alexander Garden, of Charlestown,

* These depositions were juridically taken in October, 1725, to decide a wager on this subject, which wager is said to have amounted to the whole fortune of the loser, though the greater part of it was afterwards generously restored, after having been paid. De la Ruuscher's publication was intitled, "Naturlyke historie van de couchenille, beweezen met authentique documenten;" printed at Amsterdam, by Hermanus Uytwerf, 1729.

† Rolander had been one of Linnæus's pupils, and having sent to the latter a *cactus*, stocked with the *wild* cochineal insects, (there being no other at Surinam) the plant was brought to Upsal whilst the Professor was delivering a lecture, and when he afterwards inquired for it, the gardener told him, he just cleaned away the *vermin*, which he supposed the cochineal to be, and had planted it. And as none of the insects could be found alive, Linnæus's description must have been made from those which were dead.

South Carolina, for some of the joints of that plant, with the insects thereon, which were accordingly sent the latter end of that year, and laid before the Royal Society. "These specimens (says Mr. Ellis) were full of the nests of this insect, in which it appeared in its various states, from the most minute, when it walks about, to the state when it becomes fixed and wrapt up in a fine web, which it spins about itself.

"In order to find out the male fly, (continues he,) I examined all the webs in these specimens, besides a large parcel which the Doctor had sent me picked off from the plants in Carolina, and at last discovered three or four minute dead flies with white wings. These I moistened in weak spirit of wine, and examining them in the microscope, I discovered their bodies to be of a bright red colour, which convinced me of their being the true male insect. To be confirmed in my opinion, I immediately communicated my discovery to Dr. Garden, which I accompanied with an exact microscopical drawing, and desired he would send me some account of their economy, with some male insects of his own collecting; which he did, in the spring of the year 1762, accompanied with the following observations:

"In August 1759, (says Dr. Garden), I

catched a male cochineal fly, and examined it in your aquatic microscope. It is seldom a male is met with. I imagine there may be one hundred and fifty or two hundred females for one male. The male is a very active creature, and well made, but slender in comparison of the females, who are much larger and more shapeless, and seemingly lazy, torpid, and inactive. They appear generally so overgrown, that their eyes and mouth are quite sunk in their rugæ or wrinkles; nay, their antennæ and legs are almost covered by them, and are so impeded in their motions from these swellings about the insertions of their legs, that they can scarce move them, much less move themselves.

"The male's head is very distinct from the neck: the neck is much smaller than the head, and much more so than the body. The thorax is elliptical, and something larger than the head and neck together, and flattish underneath; from the front there arise two antennæ, (much longer than those of the females), which the insect moves every way very briskly. These antennæ are all jointed, and from every joint there come out four short setæ, placed two on each side.

"It has three jointed legs on each side, and moves very briskly and with great speed.

From the extremity of the tail, there arise two long setæ or hairs, four or five times the length of the insect. They diverge as they lengthen, are very slender, and of a pure snow-white colour. It has two wings, which take their rise from the back part of their shoulders or thorax, and lie down horizontally, like the wings of the common fly, when the insect is walking. They are oblong, rounded at the extremity, and become suddenly small near the point of insertion. They are much longer than the body, and have two long nerves; one runs from the basis of the wing along the external margin, and arches to meet a slender one that runs along the under and inner edge. They are quite thin, slender, transparent, and of a snowy whiteness. The body of the male is of a lighter red than the body of the female, and not near so large."*

To Dr. Garden's description, Mr. Ellis, in

* Justice to Mr. Catesby, requires me to mention that he had some years before published the following statement in the Introduction to the first volume of his Natural History of Carolina, &c. viz. "In South Carolina grows a kind of Opuntia, which are frequently 3 or 4 feet high, from which I have *often picked cochineal* in small quantities. Both plants and insects were much smaller than those of Mexico; but the latter (i. e. the insects) were in colour and appearance the same."

an account of the male and female cochineal insects, accompanied with drawings, &c. (in the fifty-second volume of the Philosophical Transactions,) adds, that the female has a remarkable proboscis, or awl-shaped papilla, arising in the midst of the breast, which Linnæus calls the rostrum, and thinks it the mouth: "if so, (says Mr. Ellis,) besides the office of supplying it with nourishment during the time of its moving about, it is the tube through which the fine double filament proceeds, with which it forms its delicate web, in order to accommodate itself in its torpid state, during its pregnancy, till the young ones creep out of its body, shift for themselves, and form a new generation.

"In this torpid state the legs and antennæ grow no more, but the animal swells up to an enormous size, in proportion to its minute creeping state. The legs, antennæ, and proboscis, are so small with respect to the rest of the body, that they cannot be easily discovered, without very good eyes or magnifying-glasses, so that to an indifferent eye it looks full as much like a berry as an animal.

"As soon as the female is delivered of its numerous progeny, it becomes a mere husk and dies; so that great care is taken in Mexico, where it is principally collected, to kill the old ones while big with young, to prevent the

young ones escaping into life, and depriving them of that beautiful scarlet dye, so much esteemed by all the world."

I ought to have sooner mentioned that there are two sorts or varieties of cochineal; the best or domesticated, which the Spaniards denominate *grana fina*, or fine grain; and the wild, which they call *grana sylvestra.* The former is nearly twice as large as the latter; probably because its size has been improved by the favourable effects of human care, and of a more copious or suitable nourishment, derived solely from the cactus cochenillifer, during many generations. But it is only from the wild cochineal, living naturally on some of the *opuntiæ*, in different parts of America, that the descriptions of Brown, Linnæus, and Ellis, were taken. It must also be observed, that the grana sylvestra are not only smaller than the others, but that their bodies are covered by very fine white downy filaments, which they spin to defend themselves against cold, rain, &c. in their wild state; but which adding to their weight, whilst it yields no colour, contributes with other causes to render them less valuable.

In the month of January 1777, Mons. Thiery de Menonville left Port-au-Prince, in the island of St. Domingo, for the purpose of procuring some of the living cochineal insects in Mexico, and bringing them away, to be afterwards

propagated in the French West-India islands: an enterprize, for the expence of which four thousand livres had been allotted by the French government. He proceeded by the Havannah to La Vera Cruz, and was there informed that the finest cochineal insects were produced at Guaxaca, distant about seventy leagues. Pretending ill health, he obtained permission to use the baths of the river Magdalena; but instead of going thither, he proceeded through various difficulties and dangers, as fast as possible, to Guaxaca, where, after making his observations, and obtaining the requisite informations, he affected to believe that the cochineal insects were highly useful in composing an ointment for his pretended disorder (the gout), and therefore purchased a quantity of nopals, covered with these insects, of the fine or domestic breed, and putting them into boxes with other plants, for their better concealment, he found means to get them away as botanic trifles, unworthy of notice, notwithstanding the prohibitions by which the Spanish government had endeavoured to hinder their exportation; and being afterwards driven by a violent storm into the bay of Campeachy, he there found and added to his collection a living cactus, of a species which was capable of nourishing the fine domesticated cochineal; after which, departing for St. Domingo, he arrived safe, with his

acquisitions, on the 25th of September, (in the same year,) at Port-au-Prince, where he began immediately to form a plantation of nopals, and to take steps for propagating the two sorts or varieties of cochineal, I mean the domesticated or fine, and the sylvestra or wild; which last he found at St. Domingo, soon after his return, living naturally on the cactus pereskia. But unfortunately for this establishment, he died in the year 1780, through disappointment and vexation, at seeing his patriotic endeavours so little assisted, and his services so sparingly rewarded by the government. Mr. Thiery de Menonville's labours being thus terminated, the Royal Society of Arts and Sciences, at Cape François, having collected his papers, composed from them a treatise on the cultivation of the nopals, and the breeding of cochineal, &c. of which M. Berthollet has given a short extract in the fifth volume of the Annales de Chymie, together with an account of his own experiments for ascertaining the effects of the grana sylvestra, produced at St. Domingo, compared with those from Mexico, in dying.*

From the observations of Mr. Thiery de Me-

* The original publication (from which my account was written,) is entitled, "Traité de la Culture du Nopal et de l'Education de la Cochenille," 8vo. printed au Cape François, 1787.

nonville, it appears that there are two varieties of the nopal, or cactus cochenillifer, growing in Mexico, one called the true nopal of the Garden of Mexico, and the other the Castilian nopal, a name given to the last of these varieties on account of its singular beauty. It appears also that the wild cochineal, or grana sylvestra, when reared upon either of these varieties of the nopal, become almost as large as the fine or domesticated sort, and lose the greatest part of those fine downy filaments with which they are naturally covered, and which contribute to render them less valuable than the latter.

But besides the advantage of affording the most suitable nourishment to cochineal, the nopals have another of very great importance, where these insects are to be raised as objects of commerce; which is, that they are not beset with thorns or prickles, like most of the cacti, and particularly the opuntia, tuna, and pereskia, which, by this circumstance, render the insects nourished upon them, almost inaccessible to any who might wish to collect them: whilst the true nopal, and that of Castile, have none but soft inoffensive thorns, and the nourishment which they afford is at the same time so peculiarly well suited to the cochineal, and especially to the fine or domesticated sort, that these last, though they can subsist on some, will prosper on

no other species of cactus; and indeed the wild sort, though found naturally upon several other species of opuntia, are at present raised chiefly on the nopals in Mexico. The young insects, whilst contained within the mother, appear to be all connected *one after the other* by an umbilical cord to a common placenta, and in this order they are in due time brought forth as living animals, after breaking the membrane, in which they were at first probably contained as eggs. Being thus brought forth, they remain in a cluster under the mother's belly for two or three days, until disengaged from the umbilical cord; after which the females, for the only time of their lives, exercise their loco-motive faculties, by creeping to proper situations on the plant; and in doing this they are led by a wise instinct, to prefer the undersides of the different branches or articulations, (as being most defended from wind and rain,) where each attaches herself, by inserting her little tubular proboscis or mouth into the bark, and thus remains *fixed* to the end of life. By this insertion the female draws out for her nourishment the *colourless* mucilaginous juice of the nopal, and soon becomes covered with a fine adhesive downy substance. The male acquires a similar covering, but quits it at the end of a month, and in the shape of a little scarlet fly, jumps and flutters about for the purpose of

copulation; and having thereby secured a future progeny, he dies almost immediately after. But the female having other duties to perform, outlives the male another month; at the end of which she is ready to bring forth her young, and this is the precise time for gathering those which are not wanted for breeding; which is done by pressing the dull blade of a knife between the under surface of a branch of the nopal, and the clusters of insects attached to it, when the latter, being thereby separated, fall upon cloths previously spread on the ground to receive them; and a sufficient quantity being thus collected, they are dipped (enclosed in a linen cloth or bag) into boiling water, and suffered to remain in it so long as is necessary for killing them, but no longer, lest the water should extract some of their colour. This being done, they are thoroughly dried, by spreading and exposing them to the rays of the sun, by which they shrink so as generally to lose about two-thirds of their former weight. This, which has been found to be the best method of drying the cochineal, is now generally practised, though others were formerly in use; such as ovens, flat baking stones heated, &c.

Mr. Thiery de Menonville describes the male of the domesticated or fine cochineal as perfectly similar to that of the wild in every respect, excepting its size; nor does there appear

to be any considerable difference between the females of these two varieties. The domesticated female, instead of that downy covering, which enables the wild to bear inclement seasons, is only covered by a fine white powder or farina, serving in some degree as a defence against rain and cold, but not enough to enable her to remain abroad like the wild insects during the rainy seasons, which occur twice in every year. When these approach, the domesticated insects are all gathered and dried, excepting only those intended for breeding a future stock; which are preserved, by either removing the nopals inhabited by them, into situations where they are secured from wind and rain, or by raising frames over them, and covering them with thatch or matting, until the return of favourable weather; but the wild insects, being more hardy, as well as more prolific, when once placed upon the nopals, would not only perpetuate, but multiply themselves, without any farther care, to such a degree as to exhaust and destroy the plants, were they not all collected at the end of every two months, and the plants perfectly cleansed (by wiping them with wetted cloths) from the down and other animal impurities left on their branches. The nopals become fit to nourish the cochineal at the end of eighteen months from the time they were planted. The quantity of fine or domesticated

cochineal, which a single nopal can nourish, usually weighs a third more than it could nourish of the wild. These last have also the disadvantage of selling for a much less price; but in return, they are gathered six times in each year, whilst the fine yield but three crops in the same space, their propagation being wholly suspended during the rainy seasons.

In Mexico it is thought necessary to keep the two sorts or varieties of cochineal separated, at the distance of about one hundred perches from each other, lest the males of the wild, by impregnating the females of the other sort, should occasion a degeneration of the latter; a circumstance which seems to indicate that both sorts originated from the same stock, and that the domesticated is only an amelioration of the wild cochineal, through the favourable effects of a more suitable nourishment, and of warm covering; and this is rendered the more probable, by Mr. Thiery de Menonville's observation, that the former are never found in the fields or forests of Mexico, nor indeed any where but in the gardens and plantations of those employed in rearing them. But if the present size, appearance, and habits, of the domestic cochineal, were those which naturally belong to the insect, it might be supposed capable of maintaining an independent existence, remote from the dwellings, and without the help of

mankind, as it must have done before its properties were so well known as to render it an object of human care and protection; and in that case, some of this sort of cochineal doubtless would have continued to subsist in their natural state, since the whole of a race, composed of so many minute individuals, could not have been taken and brought under the protection and dominion of man. Nor is it easy to explain why none of them ever are found in a wild state, but by supposing them to have been rendered effeminate by luxurious food, and by protection from inclement weather; and that, consequently, they have been enabled to lay aside their natural downy clothing, as sheep lay aside their wool, when, after being removed to warm climates, they find it no longer necessary; and that their natural habits and means of self-preservation being lost, they are rendered incapable of subsisting without a continuance of the same fostering care which first occasioned their effeminacy; or, if they ever do find means to subsist without it, they do so only by regaining their natural downy covering, and by returning again to their primitive habits, so as not to be any longer distinguishable from those who were never out of the wild state.

After the death of Mr. Thiery de Menonville, the stock of fine or domesticated cochineal, which he had multiplied in the garden at

Port-au-Prince, was suffered to perish by neglect; but the hardier wild sort, having found means to subsist, though neglected, was afterwards taken under the care of Mr. Bruley, (substitute of the attorney-general of that province,) who, from the remains of Mr. de Menonville's establishment, formed a plantation for propagating and multiplying these insects, of which he sent a considerable quantity, in the year 1787, to the minister of the French marine at Paris, at whose request the Royal Academy of Sciences commissioned M. Berthollet, and three others of its members, to cause proper experiments to be made therewith, which they accordingly did, under their own inspection, at the celebrated establishment of the Gobelins near Paris; and from these experiments it appeared, that the grana sylvestra of St. Domingo afforded colours by dying, exactly similar to those of the Spanish fine cochineal, allowing only after the rate of twelve ounces of the former for five of the latter. Mr. Bruley some time after sent to France a second parcel of the same cochineal, produced from his plantation in the year 1788; and this being tried by the same commissaries of the Royal Academy, though in different ways, produced nearly the same effects.

Very considerable differences of *external* colour or appearance occur in different parcels of

the fine cochineal; probably, because the white farinaceous powder, with which these insects are naturally covered, is more or less washed off by the hot water in which they are killed by immersion, as well as by other circumstances which occur in the drying and packing. When this powder has been entirely removed, the insects appear of a chocolate colour, inclining a little to the purple, and they are then called *renigrida*. Generally, however, so much of the white powder remains, especially in the little furrows which cross the insect's back, as occasions a greyish appearance, called *jaspeada*; and sometimes, indeed, this powder so perfectly covers the cochineal, as to render them all over white. This I remember to have been particularly the case with a parcel which a friend of mine had purchased, and which was refused by several dyers to whom it had been sent, from a persuasion of its having been fraudulently covered by white lead, or some other metallic calx intermixed with it, to increase the weight; and one very eminent dyer alleged, that he had formerly seen and tried a similar parcel, and that the white powder had been found to consist principally of a preparation of mercury. That I might be enabled to ascertain whether an opinion so unlikely had any foundation, my friend caused several ounces of this powder to be separated from the insects by sifting; and

having tried it sufficiently, I found it to be entirely of an animal nature, and apparently nothing but the farina which naturally covers these insects. It even yielded a considerable portion of the true cochineal colour, and dyed good scarlets in the usual way, though it probably was assisted by some of the limbs or other parts of the bodies of the insects, separated by rubbing in the sieve: but I am persuaded that a part of the colour in question naturally existed in the farina or white powder itself; and if this be the case, it would be highly advantageous to contrive means for killing the cochineal, without washing off any part of the powder in question, which might, I think, be done by putting them into tinned vessels, made so as to shut closely, which might be plunged into boiling water, and withdrawn at a proper time, without letting a single drop of water come into contact with the insects, or carrying off any of the powder in question. And perhaps this method might be used with advantage, even if it should be found that no colouring matter resides in the white powder, since it is difficult to conceive that the cochineal can be plunged into boiling water, so as to wash away the powder entirely, (as is frequently done,) without a loss of some part of the colouring matter contained in the bodies of the insects themselves. In general, therefore, it will be

safest to choose that cochineal which is large, plump, clean, dry, and of a *silver white* colour on the surface.

The true original grana sylvestra seem to have been very different from the composition which is at present sold under that denomination in this kingdom, and which has the appearance of a dry powder, with many small lumps or fragments of something which had been previously formed into a cake or dried uniform mass. It affords, though in an inferior degree, some of the same sort of colour as cochineal, but in a small proportion; six pounds being necessary, according to my experiments, to dye as much cloth as one pound of the fine cochineal; whereas the true grana sylvestra are represented as yielding at least half as much as the fine, and they sell for at least half the price in some parts of Europe, whilst here the substance so called, and which has not the least appearance of any insect, sells at present for less than an eighth of the price of fine cochineal. Probably it is composed of the white downy substance which the wild insects are represented as leaving in great abundance on the nopals, and of other excrementitious matters deposited by them, joined to fragments, broken limbs, and dust, of the insects themselves, and perhaps with an addition of some vegetable matters, all beat up into one uniform mass. Something of this sort

was formerly practised even with the true cochineal, according to Dr. Brown, who says, "The cochineal insects used to be prepared by pounding them, and steeping the pulp in the decoction of the texuatla, (a species of melastoma, as he supposes,) or that of some other plants, which they observed to heighten the colour. This (continues Dr. Brown) was left to settle at leisure, and afterwards made into cakes and dried for the market." Hernandez also mentions that in his time *cakes* were made from cochineal in Mexico. Probably the true grana sylvestra, mixed with fragments of the true cochineal, compose what is sold in this country under the name of Granillo, which appears, as the name indeed imports, to consist chiefly of insects somewhat smaller than those composing the fine cochineal, and therefore, in that respect, answers to the best authenticated descriptions of the wild cochineal.

It had been generally believed that the cochineal derived its colour from the red or crimson fruit of the nopals, and other species of opuntiæ; and I was formerly induced by this opinion to make various trials with the red fruit of the cactus opuntia for dying, instead of cochineal. They all, indeed, proved unsuccessful; but I was disposed to attribute my failure to the want of that kind of animalization, which the vegetable red colouring matter was

supposed to receive, when eaten and assimilated by the insect: and I thought it probable, that other vegetable colouring matters might be equally improved in the same way, and that perhaps, instead of insects, it might be advantageous to employ larger animals for this purpose.* It is, however, now certain, from the observations of Mr. Thiery de Menonville, and from other well-attested relations, that the cochineal insects *do not feed on the red fruit* of the cactus, but upon its branches or articulations, to which they adhere, and which *contain nothing like a red juice;* and that they sometimes live, propagate, and preserve their colour on those species of cactus which *do not bear red-coloured fruits:* consequently, the colour of these insects does

* Dr. Garden relates, that a negro woman in South Carolina, who then gave suck, having eaten six of the red fruit of the prickly pear, (cactus opuntia) and some of her milk being collected, and left until the cream had separated, this last was found to be of a reddish colour, considerably weaker, indeed, than the lively red which the urine was found to acquire by the same fruit. See Philosoph. Trans. vol. 50, p. 269. In the third vol. of the same Transactions, mention is made of a berry growing in Bermudas, and called the "Summer Island Redweed, which berry is as red as the prickly pear, and giving much the like tincture; out of which berry cometh out first worms, which afterwards turn into flies, (somewhat bigger than the cochineal fly,) feeding on the same berry, in which there hath been found a colour no whit inferior to the cochineal fly."

not result from that of their food, but from their peculiar constitution and organization.*

* Although the facts here stated were published more than 18 years ago, the error which they were intended to correct, not only subsists, but continues to be propagated by weighty authorities. M. Fabroni, who was lately mentioned at p. 289, asserts, (Ann. de Chimie, tom. xxv. p. 301) that the cochineal insect can with its proboscis extract from the nopal its juice, which afterwards communicates its fine red colour to the insect; and this juice, he adds, "selon moi, est le même que la nature nous présente à *nu* dans les *fruits mûrs* de cette même plante."

Bouillon La Grange also endeavours to maintain the same error, in his Manuel de Chimie, tom. ii. p. 743, where he asserts that the cactus coccinilifer "communique son *suc rouge* à l'insecte, qui s'en nourrit." But a more important support has been given to this error by the author of a respectable botanical work, now publishing in Jamaica, under the title of Hortus Jamaicensis, in two volumes 4to. who not only adopts the error, but, to confirm it, has (vol. i. p. 412) adduced copious extracts from Mr. Long's History of Jamaica, (a work in great estimation) of which extracts the following are a part, viz. "This juice (of the fruit of the cactus) is the natural food f the cochineal insect, which owes to it the value and property it possesses, as a dye in some of our principal manufactures. The exuvia and animal salts of the insect are, from the minuteness of its parts, inseparable from the essential principles of the dye; whence it follows, that such a heterogeneous mixture must necessarily destroy the brilliancy of colour inherent to the juice of this fruit; and that the juice itself, which alone contains the dying principle, must, if unmixed and brought to consistence, yield a true perfect colour, lively and brilliant, as we find it in its natural state."

"Upon this hypothesis, Mr. David Riz, an ingenious gen-

The very great demand for cochineal, almost immediately after it had been made known in

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tleman of Kingston, in this island, proceeded in several experiments to obtain from the plant artificially, what nature accomplished in the insect, and at length happily succeeded, by inspissating the juice; but the means he used are not yet communicated to the public. Encouraged by this discovery, he went to England with seventy-six processes, differently manufactured, to try which would answer best as a substitute to the cochineal. After a great number of experiments, he found one process which communicated a crimson colour to silk and wool, superior to that given by cochineal; trials of which were made before a number of the principal dyers in and about London, at the *Museum of the Royal Society*, invited there for that purpose. He also found two other processes, which promised, with very little alteration in their manufactory, to afford the colour-making dyes of scarlet and purple. Upon a moderate calculation it was found, that his colour would go further than *three* times the quantity of cochineal, which he accounted for by remarking, that there is a great part of the insect, as its skin, &c. which affords no dye, but that the whole of his process was genuine colour, with little or no impurity."

"Notwithstanding the advantages that might be derived to the nation from this gentleman's discovery, he met upon the whole with very little encouragement to prosecute his manufacture further." Long's History, &c. p. 731.

Upon this statement I shall only observe, that if, in fact, Mr. Riz did, as is alleged, produce any substance or preparation capable of dying a good scarlet, and of producing as much colour as three times its weight of cochineal, he must have obtained it otherwise than from the cactus, and probably it must have been an extract of cochineal, like those preparations commonly sold under the name of *carmine*, except that it may have contained none of the aluminous basis, or that of tin. For

Europe, caused a very rapid multiplication thereof in the Spanish American settlements. It appears from Acosta's statement, that so early as the year 1587, there came to Spain, by a single flota, no less than 5670 arobas of fine cochineal, which, at the rate of 25lb. each, weighed 141,750 pounds; and the common annual importation, as stated some years since by the Abbé Raynal, has amounted to 4000 quintals, or 400,000lb. weight of the fine cochineal, 300 quintals of the grana sylvestra, 200 ditto of granillo, and 100 of cochineal dust, which were computed to have sold for a sum equi-

what purpose such an imposition was practised, I am not bound to inquire. But certainly the *red* fruit of any and every species of cactus, is as incapable, *as a cranberry*, of affording a colouring matter similar to that of cochineal; and since it has become notorious that this insect does not meddle with the fruit, (the only part of the cactus which exhibits a red colour) the notion which I now combat, has been left without any foundation or probability. I have already stated that the colouring matter of the kermes, is similar to that of cochineal, and yet no body has ever suspected the kermes to derive its colour from the leaves of the oak, on which it is produced, there being no *red* juice in these leaves, nor indeed, in those parts of the cactus to which the cochineal insects *attach* themselves *exclusively*. An error similar to the preceding, seems to have subsisted formerly in regard to the *purple-giving murex*, as mentioned by Aristotle (Hist. Animal. vi. cap. Ed. Scaliger,) who says that a sea-weed (Fucus) probably Orchella, having been cast on shore near the Hellespont, which yielded a purple colour, the neighbouring inhabitants concluded it to be the *food* of the purple shell-fish.

valent to about nine millions of French livres; without reckoning considerable quantities sent directly from America to the Philippine islands, for supplying a considerable part of Asia. The European importations have, however, been considerably increased, during several of the last years.* Since, according to very good information, which I have received, the quantities of fine cochineal brought to Spain in the years 1788, 1789, and 1790, amounted to eleven thousand bags, weighing 200lb. each, and making together 2,200,000lb. weight; and between the 1st of January 1791, and the 1st of October in the same year, the importations had exceeded 2000 bags.

It must, however, be observed, that the importations during these years were somewhat greater than usual, because an advance in the price of cochineal in Europe had induced the holders of it in America to send their stocks more speedily to market, in order to avail themselves of the higher prices; and, from accurate calculations, I think it may be concluded, that the average quantity of fine cochineal annually consumed in Europe amounts to about three thousand bags, or 600,000lb. weight, of which about 1200 bags, or 240,000lb. weight, may be considered as the present annual consumption of Great Britain. A greater quantity comes in-

* This was written in 1793.

deed into the kingdom, but the surplus is again exported to other countries. These 1200 bags may be supposed to cost 180,000l. sterling, valued at 15s. per lb. which has been about the average price for some years past.* According to Don Antonio Ulloa, the greatest quantities of cochineal are produced at Oaxaca, Tlascala, Chulula, Neuva Gallicia, and Chiapa, in New Spain, and at Hambatio, Loja, and Tucuman, in Peru.

About six years ago, Dr. James Anderson, physician-general on the company's establishment at Madras, persuaded himself that he had found the true cochineal insects subsisting naturally on a species of salt grass in that part of India; and some parcels of a dried insect, probably of the coccus kind, (but more like the kermes,) which he mistook for the true coccus cacti, were sent by him to this country; of which I made several trials, at the request of a friend, (as others also did,) and found them to be neither of the same species, nor possessed in any degree of that particular colouring matter for which the cochineal insect is so highly valued;

* Since the year in 1793, the price of cochineal has more than doubled; it has continued during the last eight years at more than 30s. the pound, and has sometimes exceeded 50s. But this augmentation of price, or a change of fashion, seems to have considerably diminished the annual consumption of Great Britain, which may now be estimated at about 750 bags.

though in their dried state they had nearly the same external appearance, excepting their size, which was considerably less than that of the true Mexican cochineal; but upon rubbing them in a mortar, I soon perceived, that instead of breaking into a dry powder like cochineal, they could only be beat into a kind of unctuous paste; nor would any degree of drying, short of combustion, overcome this unctuous quality, or render them capable of being rubbed into the form of a powder; and in point of colour there was a more essential difference, since they produced nothing better than a chocolate brown, by the means usually employed for dying scarlet with cochineal, nor indeed by any other means. This chocolate colour proved indeed sufficiently durable on wool; but it may be dyed so cheaply by other matters, and indeed these insects yielded so little of it, that they never can be worth collecting as a dying drug.*

It occurred to me, however, on this occasion, that though Dr. Anderson had failed in his ex-

* The Company, in their letter of the 31st of July 1787, to the government of Madras, were pleased, from very laudable motives, to direct, that every further pursuit respecting this species of insects "should be effectually discouraged," because "were it to fall into the hands of improper persons, it might be made use of to mix with and adulterate the real cochineal, to the great injury of the consumer, as it would most assuredly spoil the beauty of every scarlet done therewith."

pectation of finding the cochineal in a country where it probably never existed, (the genus of plants on which it is naturally fitted and destined to live having been originally produced only in America,) yet it would not be very difficult to convey both the insects, and the cactus cochenillifer (their natural food and habitation) to the East Indies, and there propagate both, so as in a few years to obtain from thence ample supplies of a drug so highly important in a great manufacturing country, and for which nearly 200,000l. sterling are annually paid by this to the Spanish nation, especially as great advantages in this respect would result from the cheapness of labour and subsistence in the East Indies; and considering moreover how much the quality of the indigo of that country had been improved, and the quantity increased within a few years, through the measures taken so opportunely for these purposes by the East-India Company, at a time when the usual supplies of that article from other countries had been greatly diminished.

Similar ideas on this subject occurred, or were suggested, to the Directors of the East-India Company, who, in the spring of the year 1788, procured from his Majesty's botanic garden at Kew (through Sir J. Banks, Bart. P. R. S.), some of the *true nopal plants*, two of which were sent out by the Bridgwater, during that

season, to Madras, and put under the care of Dr. Anderson, where they have since been multiplied to several thousands,* and been transplanted from thence to Bengal, and St. Helena, in order that a sufficient stock might be in readiness to receive any cochineal insects which should arrive; a committee of the Directors having previously reported as "their opinion, that it be recommended to the Committee of Correspondence to take such measures as they shall judge best suited for procuring from America a quantity of the cochineal insect, with a view to the introduction of the same upon the coast of Coromandel." Unfortunately, however, it does not appear that any measures have yet been effectual in procuring the domesticated insect, or even the sylvestra, though this last exists in Jamaica, (as does the true nopal†) and in many other accessible parts of America, and probably in more than ordinary perfection in Brasil; at least I made trial about the year 1787 of some which had been sent from thence by

* It has since been ascertained that these plants were not the true *nopal*, or cactus coccinillifer, but a different species, much less suited to the purpose for which they were intended.

† The cactus coccinillifer, and the cactus Pereskia (or Spanish gooseberry), are both mentioned in a recent catalogue of the *Hortus Eastensis*, as growing in the botanical garden of the late Mr. East, at Jamaica; and others are said to be growing in Longville Garden, in the same island.

the way of Lisbon, and which yielded *full* as much colour, and of as much beauty, as half its weight of the *very best fine cochineal;* and until this last can be obtained, would it not be advisable to make trial of the other, which, by being properly nursed, and nourished upon the true nopals, might perhaps, in a little time, improve so as to supersede the necessity of seeking any farther?*

* Subsequently to this suggestion, and as I believe in consequence of it, some of the Brasilian cochineal insects were carried to India by one of the Company's ships which had touched at that part of America, and some quantities of cochineal have been at different times imported to this country, which were derived from the Brasilian *stock*. I had collected authentic and valuable information on this subject, and had made experiments with the cochineal itself; but the papers containing an account of them, and of the information so collected, have been unaccountably lost or purloined, with others, probably of more importance, and I dare not rely on my recollections so far as to enter upon any statement of their contents.

CHAPTER IV.

Of the Properties and Uses of Cochineal; with an Account of new Observations and Experiments calculated to improve the Scarlet Dye.

"Le travail a été mien, le profit en soit au lecteur."
JEAN REY.

IN the English translation of Clavigero's History of Mexico, the ancient inhabitants of that country are said to have obtained a *purple* colour from cochineal. Probably, however, either the author or translator of that work, has mistaken purple for crimson; this last being the *natural* colour of cochineal, and what it always affords with the aluminous basis, which Clavigero, in another part of his history, says the Mexicans had been used to employ in early times; though it certainly is difficult to understand how they could have become acquainted with it. This account moreover accords with that of Herrara, who, after mentioning the Tuna or Nopal of Tlaxcalla, says, "Optimum longè granum dat Tlaxcallum cujus indigenæ prestantissimam tincturam ex illo conficiunt, hoc modo, comminuunt & macerant in decocto *aluminis*, & ubi resederit, cogunt in tabellas, quas Hispani vocant *grana en pan*."*

* Whilst alum was the only mordant employed with cochineal, these *grain cakes* made with a decoction of alum might answer very well, but not afterwards.

There is also reason to conclude, that during a number of years, none but the aluminous basis was used for dying with cochineal in Europe,* until the accidental falling of a solution of tin by aqua-fortis, into a decoction of cochineal, about the year 1630, manifested the singular power of the oxide of that metal in *exalting* the colour of this drug, and led to a discovery of that most *vivid* of all colours the *cochineal scarlet*. Kunckel and others state this accident to have happened to a German, named *Kuster*, or *Kuffler*. But others, and particularly Beckman, assert that it occurred to a Dutch chemist, Cornelius Drebbel, who was born at Alkmaar, and died at London in 1634,† and that he communicated this occurrence to Kuffler, who was an excellent dyer at Leyden, and afterwards became the son-in-law of Drebbel.‡ That Kuffler

* Caneparius (de Atramentis, p. 191), mentions the dye "ex granis ficus Indicæ Mexicani, quæ prout semina sunt, eisque tinctores pro *carbisino* colore utuntur." Hence it appears that cochineal was then (1619) only used for dying crimson, at Venice, where the art of dying had long been most successfully practised.

† If it be true that Drebbel died in London in 1634, he had probably come to England to derive some benefit from his discovery, and died before he had had time to do so.

‡ Mr. Macquer, in a memoir printed among those of the Academy of Sciences of Paris for 1768, says, "Drebbel, chimiste hollandois, a imaginé d'employer dans la teinture

put the discovery into practice in his dye-house, and that the scarlet was thence first named Kuffler's colour, and afterwards scarlet of Holland, or Dutch. From him a Flemish painter, Kloeck or Gluck, learned the secret, and communicated it to one of the famous Gobelins at Paris; and another Fleming, named Kepler, brought the secret to England about the year 1643, and the first dye-house for dying the new scarlet having been soon after established at *Bow*, near London, that colour was for some years called the *Bow* dye.

It has been generally supposed, that after the effects of tin upon the cochineal colour had been

de cochenille, de la dissolution d'étain faite par l'eau régale, et dès lors on a obtenu le plus vif et le plus éclatant de tous les rouges dont l'art, et même la nature nous ait donné l'idée; je veux dire l'écarlate couleur de feu, qui a porté d'abord le nom d'*escarlate de Hollande*, parce que c'est dans ce pays que les premières manufactures ont été établies," &c.

Mr. Macquer seems to have been mistaken in supposing that the first solutions of tin employed in this way were nitro-muriatic, or made with aqua-regia, there being very good reason to believe, that aqua-fortis alone, though perhaps impure, was used for some years for this purpose.

Mr. Delaval, without the smallest probability, attempts to carry the first use of tin for dying back to very remote antiquity; and thinks the Phœnicians used that which they were said to have brought from Britain in this way, because (as he erroneously asserts) "this is necessary to the production of red colours, whether from animal or vegetable materials." See Experimental Enquiry, &c.

discovered, as before mentioned, nothing more was wanting to produce what is at present called scarlet, than to apply the colour so produced as a dye to wool; or in other words, that a nitric, or nitro-muriatic solution of tin, was sufficient to change the natural crimson of cochineal to a scarlet. Such at least has been the opinion of every writer on the subject until the present hour; though it will hereafter be proved to have been an erroneous opinion, and that the nitric solution of tin invariably produces (with cochineal) a crimson or rose colour, and not a scarlet, unless other means be also employed to incline the cochineal colour, so far as may be necessary, towards the *yellow*; and the means of doing this seem to have been stumbled upon, and continually employed without any knowledge of their true effect. I have already mentioned that tartar is, and for many ages appears to have been, generally employed with alum, to compose the ordinary boiling liquor or mordant for woollen cloths: and it seems probable, that when the first attempts were made to employ the solution of tin, instead of alum, it would naturally have been imagined, that as tartar had been found useful with the latter, it must also produce good effects with the former, and that a trial of it having been thus produced, and the most brilliant of all colours having been found to result from this combination of tartar

with the solution of tin, their joint use was afterwards continued, without any inquiry concerning the particular share which either of them had in producing such pleasing effects.

At first indeed a diluted nitric acid appears to have been employed for dissolving the tin without any admixture of the muriatic;* but as the former would have held but a small portion of the calx of that metal in a state of suspension, and as even that portion would have been liable to precipitate in a few days, the practice of adding either a little muriate of ammonia, or a little sea-salt, to the aqua-fortis, and of thereby producing an aqua-regia, or nitro-muriatic acid, seems to have been introduced, though it did not become general until a considerable time after; since Hellot gives an account of the process used in his time for dying scarlet at Carcassonne, in which tin was dissolved *only* by diluted aqua-fortis; and he mentions M. Baron, as claiming the merit of having been the first in that city who employed an aqua-regia for dissolving tin, *in order to prevent a precipitation of its calx or oxide;* and even when this was done, the muriate of ammonia and sea-salt were added, but very sparingly, from a belief, which still subsists universally, that a more liberal use of either of them in this way, or of the muriatic

* Doubtless, the aqua-fortis was then impure, by containing at least a small proportion of the muriatic acid, as it commonly does at this time.

acid in their stead, would render the cochineal colour a crimson instead of the scarlet, which last is supposed to be a peculiar production of the nitrate of tin,* though nothing can be more groundless than this belief; since the nitrate, and the muriate of tin, both *equally* afford a crimson colour with cochineal, and neither affords a scarlet without the aid of other means.

The dyers' ordinary solution of tin is made with that species of diluted nitric acid, called single aqua-fortis, and which, as usually prepared, is capable of dissolving about one-eighth of its weight of tin, grained or granulated, by pouring it, when melted, into water, briskly agitated with a bundle of rods, or by other suitable means.

For each pound of aqua-fortis, it is usual to add after the rate of one or at most two ounces of sea-salt, though some prefer, and probably with reason, the muriate of ammonia for this purpose. About half as much water as of aqua-fortis, is moreover commonly added, in order still farther to dilute the acid, and moderate its action on the tin. Those solutions of it which are made most slowly, and with the least separation of fumes or vapours, have been found

* I give this denomination to solutions of tin produced solely by a diluted nitric acid, without regarding the decomposition more or less complete, which the acid undergoes in consequence of such solution.

to succeed the best; probably, because in these the tin is less calcined, or oxygenated, and the solution retains a larger portion of azote, or nitrogene, than in those which proceed more rapidly. It is usual to allot after the rate of two ounces of grained tin to every pound of aqua-fortis; and the metal is put into it, at different times, waiting until one part is nearly dissolved, before another is added, lest too much heat should be evolved, and the solution proceed too rapidly; though there is no danger of this, in the latter part of the process, which indeed should be protracted so as to last two or three days. The water mixed with the aqua-fortis should be ascertained by weighing or measuring, in order that a proper allowance may be made for it in calculating the strength of the solution, or the weight of metal contained in a given quantity thereof, which, supposing half as much water as of aqua-fortis, to have been used, will be about one-fourteenth part of the whole; and when the solution (which the dyers in this country generally call *spirit*) has been made in these proportions, from eighteen to twenty-five pounds of it are commonly employed to dye a full cochineal scarlet, upon one hundred pounds weight of woollen cloth; and of this quantity three fifths, or two thirds, are usually employed in the first preparation, or boiling part of the process; for which supposing one hundred pounds weight of cloth are

intended to be dyed, about eight pounds of crude tartar or argol are put into a suitable dying kettle or vessel, (of pure block tin,) with a sufficient quantity of clean soft water,* and six or eight ounces of powdered cochineal. Immediately after this twelve or fourteen pounds of the solution of tin, prepared as before mentioned, are to be added, and when the mixture is nearly ready to boil, the cloth, being first thoroughly moistened, (that the dye may penetrate and apply itself equally thereto,) is put into the dying liquor, and turned through it (by the winch) very quickly at first, and afterwards more slowly, whilst the liquor continues to boil, for the space of an hour and a half or more, after which it is to be taken out, and rinced in clean water. By this *first boiling* or preparation, the cloth will have acquired a flesh colour. For the *second*, or dying process, a tin vessel is filled with clean water, and when this appears almost ready to boil, five, or if a *full* colour be wanted, five and one half pounds of cochineal in powder are to be put into it, and well mixed, by stirring for a few minutes; after which, the remaining part of the solution of tin is to be added, and the whole being well stirred, the cloth is to be put into the liquor, and turned *very briskly* through it, over

* Hard water tends to produce a rose colour, which the dyers commonly endeavour to obviate, by boiling bran or starch in their water.

the winch, for a little time, in order that both ends may receive an equal portion of the dye; after which it may be turned more slowly for the space of half an hour, or until the dying liquor becomes exhausted, when the cloth is to be taken out, aired, and rinced.

An ounce of fine cochineal is generally deemed necessary for dying a pound of cloth; but something less than this portion is frequently made to answer, especially for coarser cloths.*

It is not, however, necessary to follow this (which is the usual) process for dying scarlet. I have often given that colour very well at one single though protracted boiling, by mixing the whole quantity of tartar, and solution of tin, and adding the cochineal, after the cloth has boiled ten or fifteen minutes; for such, in this case, is the attraction of wool for the colouring matter, as well as for the oxide of tin, that it will take up both very freely, and retain them permanently, when thus mixed. I think, however, that in this way the cloth may be liable to imbibe both the mordant and the colour, with some inequalities, by reason of the differences

* Hellot directs an ounce of cochineal for each pound of fine cloth. Berthollet prescribes six pounds of cochineal for every 100lbs. of cloth. Mr. Hawker, a very eminent scarlet dyer in Gloucestershire, assured me, that for fine cloths he commonly employed four pounds of cochineal for every 60lbs. of cloth; but that for coarse cloths he seldom exceeded two pounds and three quarters for that quantity of cloth.

which are found to subsist not only in the wool of different sheep, but even of the same individual, when taken from different parts of the body, as was noticed at p. 85; and that it will therefore, always be safest to employ a *previous* boiling, in the manner commonly practised, to overcome the effect of these inequalities, by forcing a sufficient quantity of the mordant or basis, into the pores even of those sorts of wool which are the least disposed to receive it. This boiling may, however, be shortened to a *single hour*, when it is performed with what the dyers call a *seasoned float*, meaning the bath or preparation liquor which, after having been employed for the same purpose, is replenished according to the ordinary practice, with a fresh portion of the mordant, &c. and thus rendered more efficacious than the *first*.

I have moreover often dyed very beautiful scarlets, by preparing or boiling the cloth with the *whole* quantity of solution of tin and tartar at once, (as is commonly done with alum and tartar,) and afterwards dying it unrinced, with the whole of the cochineal in clean water only; and in this way I have found the colouring particles so completely taken up by the cloth, that the liquor became as clear as the purest water, and the colour was generally very perfect.

Most dyers, besides the tartar used in the first boiling, employ half as much of it as of

cochineal in the second, or dying part of the process; and certainly the doing so will be advantageous, whenever the colour is wanted to approach nearer than ordinary to the orange tint, though this is not the effect which would be generally expected to result from thence. Pœrner uses no cochineal in the first boiling, nor indeed is any necessary, though a little may probably help to decompose the oxide of tin, and fix it more copiously in the fibres of the cloth. For scarlet, many dyers prefer the *red* argol or crude red tartar; but the matter to which it owes this colour is wholly incapable of adding any colour to that which the wool might otherways acquire, and therefore at best its redness will prove useless. Wool is seldom dyed scarlet until it has been spun, wove, and fulled; because the yellowish tendency which the cochineal colour acquires from tartar in the dying process, is nearly all taken away in the fulling, and a *rose* produced instead of a scarlet colour.

M. Berthollet thinks the solution of tin, before described, does not affect the cochineal colours, *merely* by the proportion of that metal which it contains; and that when either sal-ammoniac, saltpetre, or common salt, enter the composition of an aqua-regia, the compound will be less acid than when it consists of the nitric and muriatic acids solely; and that the former deserves therefore to be preferred, as

having a less violent action upon the fibres of woollen cloths, and upon colouring matters.

It is remarkable, that during the present century, no considerable improvement has been made in the process or means of dying scarlet; a circumstance which is the more extraordinary, since the pre-eminent lustre, as well as the costly nature of this dye, have rendered it an object of particular attention, not only to dyers, but to eminent chemists, by whose researches we might have expected, that at least every obvious improvement therein would have been long since attained. That this, however, has not been done, will, I think, manifestly appear, by the following statement of my own particular observations and experiments on this subject, which began in the year 1786. Having then been led to pour boiling water repeatedly upon powdered cochineal in a china bason, and to decant it as often from the subsiding insoluble parts, until they would yield no more colour, I found that by adding a little pot-ash, or soda, to this seemingly exhausted sediment, and pouring fresh boiling water thereon, a farther copious extraction of colour instantly displayed itself, equal, as far as I could judge, to about one-eighth of the whole of that which had been originally contained in the powdered insects; and having by repeated trials, constantly found this effect, I too hastily concluded, that the colour thus obtained by the help of pot-ash,

was so far of a resinous nature, or so intermixed with a resinous matter, as to have always been incapable of being extracted by the means usually employed for dying with cochineal; and that if it should be found capable of yielding colours as beautiful and permanent as those dyed with the more soluble colouring particles of these insects, an acquisition might be made of so much *new* colouring matter, which till then had, as I conceived, been always thrown away. That it was capable of yielding such colours, I soon ascertained, by repeatedly extracting this particular colouring matter by the help of pot-ash, and afterwards dying small pieces of cloth with it, (in the ways usually employed for dying scarlet), and by comparing and exposing them to the weather with other pieces dyed from the more soluble colouring matter of cochineal.

Continuing my inquiries on this subject, I soon perceived that the colour, denominated scarlet, must in fact be a compound colour, (like green, purple, and orange), consisting probably of about three-fourths of a most lively pure crimson or rose colour, and about one-fourth of a pure bright yellow; and that therefore, when the natural crimson of the cochineal is made scarlet by the means always hitherto employed for dying that colour, there must be a *change* produced, equivalent to a conversion

of one-fourth of the cochineal colouring matter from its natural crimson to the yellow colour; and as a better yellow might be obtained from other drugs, where it naturally exists, and for a fiftieth part of what it costs when obtained in this way, from the *most costly of all dying drugs* (cochineal), it necessarily followed, that this, the universal and only known method of producing a scarlet, must be highly injudicious, because unnecessarily expensive.

Convinced of this important truth, and at the same time believing too easily, on the autherity of Hellot, Macquer, and others, that the natural crimson of cochineal was rendered scarlet only by the nitric acid employed to dissolve the tin used in dying that colour, I began a series of experiments for producing it, without any such *waste* of the cochineal colouring matter. For this purpose it seemed necessary to discover a mordant or basis, capable of permanently fixing and strongly reflecting the pure vivid cochineal crimson, or rose colour, without making it incline to the yellow. I concluded, and found by experiments, that the necessary *purity* and *vivacity* of colour could not be obtained from an aluminous basis, however dissolved, though it doubtless fixes the colouring particles of cochineal more durably than any other mordant; and the like defect was found to accompany the solutions of all the other earths, as

well as of the metals, tin alone excepted; and with this farther disadvantage, that most of them either degraded or altered the natural colour of cochineal very considerably. It followed, therefore, that a basis to suit my purpose must be sought for in the pure white calx or oxide of tin, so dissolved or combined, as to reflect the cochineal crimson unchanged, and with the greatest possible lustre. Misled by what those eminent writers Dufay, Hellot, Macquer, Scheffer, &c. had advanced, as well as by the opinions of others, with whom I had conversed on this subject, I erroneously concluded, that all solutions of tin, in which the nitric acid predominated, would necessarily incline the cochineal crimson towards the yellowish tint, and that therefore such solutions ought to be excluded from my experiments. In this persuasion, I dissolved parcels of that metal in almost every other acid, and tried them separately for dying with cochineal. Their several effects will hereafter be more particularly stated: at present I need only mention, that of all others the muriatic solution seemed the best suited to answer my purpose, as it both fixed and reflected the pure crimson or rose colour of the cochineal unchanged,* and with the utmost

* It must be observed, that when in this and other places I mention the crimson colour as produced by cochineal upon a tin

brightness. To produce a scarlet, therefore, it was only necessary to superadd, and intimately combine with this crimson or rose colour, a suitable portion of a lively golden yellow, capable of being properly fixed and reflected by the same basis. Such a yellow I had previously discovered in the *quercitron* bark, (which will be the subject of a future chapter,) and also in what is improperly called young fustic, (Rhus Cotinus, Linn.) though its colour was less bright, and less durable, than that of the quercitron bark. This last had also the advantage of being not only the brightest, but the cheapest of all yellows, since one pound of the bark in powder, which cost but three-pence farthing, dyed, with a sufficient quantity of muriate of tin, between thirty and forty pounds weight of woollen cloth of a full bright golden yellow; and this being afterwards dyed in the same liquor, with one-fourth less of cochineal than what is usually employed, acquired a scarlet equal in beauty and durability to any which is usually given by the ordinary means, with a full proportion of cochineal; and such were the general results of a great number of experiments.

basis, I mean a colour much more lively and beautiful than the crimson dyed from cochineal upon an aluminous basis. The former might, perhaps, with more propriety, be denominated a *rose* colour.

The quantity of muriatic solution of tin necessary to dye a given quantity of scarlet in this way, seemed to me at that time to depend on the proportion of metal contained in it, and this last to depend on the strength of the acid used for this purpose.* That which I employed, and which I bought at the price of 38s. per 112lbs. or about four-pence per pound, dissolved in a strong sand-heat, one-third of its weight of granulated tin; and this solution would, with the proportions of cochineal and bark before mentioned, dye about ten times its weight of cloth, of a good scarlet colour.

I have said that three pounds of muriatic acid, which cost but one shilling, might be made to dissolve a pound of tin, which would require eight pounds of single aqua-fortis to dissolve it; and this quantity of aqua-fortis, at the rate of 8d. per lb. would cost 5s. 4d., so that on each pound of tin dissolved by muriatic acid, instead of the nitric, I calculated a saving of 4s. 4d. The muriatic acid, therefore, which M. Beaumé

* I have since ascertained, by decisive experiments, that muriatic acid, which has *only* dissolved *one-half* of the portion of tin which it may be made to dissolve, will go as far as an equal quantity of acid which has been saturated with the metal, and that the effects of the former are in every other respect better than those of the saturated solution, so that this last is at best an useless expenditure of one-half of the tin which it contains.

had styled the true dissolvent of tin, ("le vrai "dissolvant de l'Etain,") seemed also to be of all others the cheapest; and with this farther advantage, that a solution made by it was as transparent and colourless as the purest water, and capable of being preserved for many years, in vessels closely stopped, without the least alteration, whilst the dyers' nitro-muriatic solution of tin or spirit becomes turbid or gelatinous very speedily, and even in a very few days, if the weather be warm.

I may add also, that the muriatic solution of tin seemed to exalt the colours both of the quercitron bark and of cochineal, more than any other.

I perceived, moreover, another advantage resulting from this new method of dying scarlet, by a saving of all the tartar employed in the old. Before I began my experiments on this subject, I had endeavoured to learn the purpose which tartar was intended to answer in the usual process for dying scarlet; but having obtained no satisfactory answer on this point, I doubted of its producing any good effect, and therefore omitted it in my first trials; and as they succeeded, I also omitted it in all the others.

By these facts and ideas I was led to believe that I had made discoveries likely to produce very important national benefits: and I particularly calculated in the first instance a gain of about 12½ per cent. upon the whole quantity of

cochineal consumed in Great Britain, by that part of its colouring matter, which I proposed to extract by the help of pot-ash, or soda, and which I supposed to have been before always lost.

Besides this, I computed that a saving of 25 per cent. upon all the cochineal used in Great Britain for dying scarlet, aurora, and orange colours, would result from my plan of obtaining from the quercitron bark so much yellow as was required for the composition of those colours with the cochineal crimson, instead of converting any part of this last more costly colour into a yellow. And lastly, I calculated other savings, equal at least to 20,000l. annually, in the article of tartar, (acidulated tartrite of pot-ash,) and in what the muriatic solution of tin was likely to cost less than that which is commonly used for the purposes in question.

With this opinion of the importance of my discoveries on this subject, I gave an account of them, as well as of an improvement in the black dye, (which will be hereafter explained,) to the Right Honourable the Lords of the Committee of his Majesty's Privy Council, appointed for the consideration of all matters of trade, &c. (of which committee the late Earl of Liverpool was President), and their lordships, with a laudable solicitude for the public welfare, were pleased, by an order, bearing date at Whitehall,

the 18th of September, 1787, to refer the same to " six capital dyers, named in the said order, who were desired to inquire into the facts respecting the said important discoveries in the black and scarlet dyes;" and afterwards " to report to the committee their opinion of the merits and utility" thereof.

It was not, however, until the 22d of January following that an experiment relating to the scarlet dye was made at the dye-house of Messrs. Goodwin, Platt, and Co., Bankside, Southwark. Considering, on that occasion, how much practical operators, in all the arts, are inclined to distrust improvements offered by speculative men upon the grounds of theory or philosophical reasoning, I was desirous of making my first trial, under the most favourable circumstances, in order that by its signal success, I might effectually obviate the effect of any unfavourable prepossessions in the minds of those who were to report on the merits of my discoveries. For this purpose I prepared a large quantity (near 100lb.) of the muriatic solution of tin; and in order that the acid might be perfectly saturated with the metal, I added an overproportion of the latter, and kept both at the boiling point, by means of a sand heat, for the space of three days and nights. In this way I obtained a solution perfectly colourless, of a very pungent smell, and so highly volatile and elastic,

that it was impossible to prevent its escape from the vessels in which it was contained, however closely stopped. It was, in fact, but little different from the fuming liquor of Libavius, in which dry muriatic acid is saturated with tin; but this complete saturation, instead of proving beneficial, as I had expected, became an obstacle to my success; because the union between the acid and the metal was thereby rendered so intimate and powerful, that the affinities of the cloth and the colouring matter of the bark could not overcome it, except in a degree too small to afford a sufficient basis for the cochineal colour; and farther quantities of the solution being therefore added, to supply this deficiency, (from an erroneous notion respecting the cause of it) the texture of the cloth was by these additions greatly weakened and injured.

Two pieces of long baize, weighing together 188lbs. had been chosen as the objects of this experiment. I had before observed, in my private trials, that the colour generally proved most lively when given with a full proportion of the muriate of tin; and also that the colouring matter of the cochineal was most completely imbibed and *taken up* out of the dying liquor by the cloth, when the whole portion of the solution of tin, instead of being applied at different times, was boiled up *at once* with the quercitron

bark; an effect the more desirable for me at that time, because I intended to employ a very small proportion of cochineal, and therefore wished to leave as little as possible of its colouring matter behind, floating in the dying liquor, especially as it would be difficult properly to estimate the exact quantity remaining therein.

For these reasons, I took a large portion of the solution of tin, *i. e.* 16lb. weight for the two pieces of baize, and threw the whole of it at once, with five pounds of powdered quercitron bark, into a suitable *tin vessel*,* properly filled with water a little warmed, into which the pieces of baize (previously moistened) were soon after put, and turned as usual over a winch through the liquor (which was made to boil) for the space of an hour, when they were both taken out and rinced in clean water, the dying

* For a considerable number of years, the scarlet colour had been constantly dyed in vessels made, or consisting wholly of block tin. Very lately, however, it has been found that copper bottoms might be given to these vessels without injuring the colour, and with a great saving of expence, as they prove much more durable, and the copper is but little acted upon when secluded from atmospheric air, by being covered with water, &c. and even in the dying operation, the acids are more disposed to exert their *action* upon the *tin* of which the upper part of the vessel consists, and upon the cochineal and the cloth, than on the copper bottom.

vessel being at the same time emptied, and then filled again with warm water for the remaining part of the operation. The baize had, in this first boiling, acquired a very bright golden yellow, though but about one-fortieth part of its weight of bark was employed; and I had expected, from what had before happened in my own particular experiments, that it would have been so fully impregnated by the metallic basis, as to want no farther addition of the muriate of tin in the second part of the process. To secure myself, however, against a disappointment on this point, I cut off a bit from one of the pieces, and boiling it in a small pipkin with water, and a little cochineal, I saw with great concern that the fibres of the cloth were very far from having imbibed enough of the oxide of tin to fix and raise the cochineal colour; and that a farther portion of the solution would be absolutely necessary for this purpose. The cause, indeed, of this disappointment, was only ascertained by subsequent experiments, though it might have been conjectured at that time, as the water into which the solution of tin had been poured in the dying vessel, did not decompose any part of it, or become in the slightest degree milky or turbid, as it does with other solutions of that metal; and the attraction of the woollen cloth was evidently much too feeble to separate and attach to itself any part of the oxide of tin,

excepting that which had united with the colouring matter of the bark, and by this additional affinity became fixed in the wool as the basis of that golden yellow which it had received, as already mentioned; whilst the other and greater part of the oxide remained in the water, (combined with the muriatic acid,) and was thrown away with it after the first boiling, but unfortunately not without having previously weakened the fibres of the wool by its corrosive property, of which I had no suspicion, until it became manifest in the second part of the operation. For this, five pounds of cochineal were put into the dying vessel, with six pounds more of the muriate of tin, and being well mixed in the water, the two pieces of baize were put into the liquor, and dyed therein for about fifteen minutes, when the colour not seeming to rise properly, four pounds more of the solution of tin, and one pound of cochineal, were added; and the dying was continued, until it appeared soon after that the texture of the cloth was greatly injured by the muriate of tin,*

* Subsequent experiments have proved, that if my purpose of employing the yellow of the quercitron bark, in conjunction with a rose colour from cochineal, would have allowed me to add the usual portion of tartar on this occasion, the injury sustained by the cloth might have been completely obviated; for the acid of the tartar, like every other acid which I have tried, greatly corrects this hurtful sort of action, which the muriate of tin

which seemed in this, as well as in subsequent trials, to have a much stronger and more corrosive action upon the fibres of wool than other solutions of that metal, though before that time I had always been persuaded that it would on the contrary have acted more mildly in this respect than the ordinary dyers' solution or spirit; and indeed I had been led to this persuasion by the concurrent opinions of several very eminent chymists, who had all represented the nitric acid as exerting a stronger and more corrosive action than the muriatic upon animal substances. Even that very excellent chymist Berthollet has observed, in the tenth volume of the Ann. de Chymie, published so lately as the month of August 1791, and after he had been particularly employed in examining the effects of the different acids upon wool and silk, that "l'acide "sulphurique & l'acide muriatique exercent une "action moins vive sur les substances animales "que l'acide nitrique suffisamment concentré." And this doubtless is true of these acids acting merely as acids; but very different properties appear to result from their combinations with

when employed *alone*, exercises on wool or woollen stuffs. The tartar would, moreover, have rendered the muriate of tin, more susceptible of *decomposition*, by affording a portion of superfluous or uncombined *acid*, so that *less* of the muriate of tin would have been sufficient.

metals, and metallic substances; among which, the metallic solutions by muriatic acid seem generally more corrosive than those made by any other. This is particularly true of the muriates of mercury, silver, lead, bismuth, and antimony, as well as that of tin; but the corrosive nature of this last, and the difficulty of decomposing it, seem to be increased, in proportion as the muriatic acid is more completely saturated or combined with a greater portion of the metal. It is indeed true, that the proportion of solution of tin used in the foregoing experiment, was much greater than I had ever before employed, as it amounted to 26lb., and contained above six pounds of the metal, which is four times as much as would suffice (dissolved by a mixture to be hereafter explained) for the same weight of cloth. But still I am persuaded, that an equal quantity of any other solution of tin would not have injured the like quantity of cloth in an equal degree; and being thus made sensible of the danger that must attend the use of a mordant so corrosive, I was convinced of the expediency of searching for one more harmless in this respect, though it certainly is very possible, with proper care, to employ the muriate of tin (containing a smaller proportion of the metal) so as to produce all the good effects which I had expected from it, without any injury to the cloth, as I have found by a multi-

tude of experiments since, as well as before, that of the 22d of January, 1787.

Whence this corrosive property of the muriate of tin arises, may become a subject of future inquiry. At present I shall only observe, that in some experiments which I made, with the hope of correcting it, I constantly found this saturated muriate of tin, possessing a strong attraction for oxygene, and that by absorbing it, as it did from various matters, its corrosive property was always greatly diminished. This led me to oxygenate the muriatic solution of tin, by putting a very little manganese into it, or rather by dissolving tin with a very little manganese in muriatic acid; but though the solution made in this way appeared less corrosive, it contained a small portion of the manganese, which darkened the cochineal colour, making it incline towards a purple.

I afterwards oxygenated the muriatic acid, by mixing it with about one-third less than its own weight of the nitric, and with this I made a solution of tin; which appearing to be no more corrosive than the common dyers' spirit, and not changing the cochineal crimson towards the yellow hue, I was hastily induced to venture with it upon another trial at the dyehouse of Messrs. Goodwin and Co. a few weeks after the first. It was, however, made only on one piece of baize, weighing about ninety

pounds, which I caused to be boiled with about eight pounds of this murio-nitric solution of tin, and two pounds and one-half of powdered quercitron bark. This mordant, however, acted very feebly, or rather failed, in exalting the *yellow* colour of the bark, which took but very slowly on the baize, and never rose much higher than a straw colour, even after two hours boiling; when a considerable quantity of yellow colour, united to the calx of tin, evidently remained floating in the water, not because the calx was too intimately combined with the acid solvent, as in the first experiment,—but because, for want of a sufficient attraction between them, it had been almost wholly decomposed as soon as they were put into water: and in boiling, it fixed itself with the bark colour upon the cloth very sparingly, superficially, and slowly. This also happened in the second part of the operation; for which three pounds of cochineal, and six of this murio-nitric solution of tin, were at first employed; but the colour not rising sufficiently, another pound of cochineal, with four pounds more of the same solution, were added to the liquor in which the cloth was dyed for the space of two hours, when a considerable part of the colour still appeared floating, but not dissolved, in the water. So much, indeed, had been applied to the cloth, as to give it a passable scarlet colour, which, however, had

penetrated but very little into its substance, so that the cloth seemed, as Mr. Goodwin observed, to have been rather *painted* than dyed.* It

* According to my best recollection, the solution of tin employed for this experiment had been made eight or ten days before it was so employed, and during this interval the metal had probably become too much oxygenated : and it had moreover the disadvantage of being used without the aid of tartar, which by its acid seems to enable the oxide of tin, as well as the cochineal colour, to penetrate and unite more copiously with the fibres of wool. I very lately (Nov. 1812), mixed three ounces of strong nitric acid of the specific gravity of 1500, with seven ounces of muriatic acid of the specific gravity of about 1165. The mixture, as is usual, effervesced, and assumed for a short space of time a deep red colour. In this mixture diluted with six ounces of water, I dissolved two ounces of fine granulated tin, and the *next day* employed a suitable portion of it, with cochineal and cream of tartar, to dye a small piece of broad-cloth. I observed, on putting the solution of tin into the water, that it collected therein like small loose dispersed *curds*, which, however, by a little boiling with the tartar, were completely dissolved, and the cloth being put into this liquor with a part of the cochineal, and boiled in it as usual, and afterwards dyed with the remainder of the cochineal and more of the solution of tin and tartar, imbibed, contrary to my expectation, a *very bright good scarlet*, excepting that it inclined a little too much to the orange tint. In this case the colour had penetrated and united itself to the cloth as expeditiously as with the solution of tin commonly employed by the dyers, and without any such difficulty as I had experienced in my second experiment at the dye-house of Messrs. Goodwin and Co. ; an advantage which must, as I think, have resulted from my having in this latter trial employed the solution of tin when *recently*

was, however, generally agreed, after a particular examination, that notwithstanding the great length of time in which the baize had been boiled with a very large proportion of the solution of tin, (*i. e.* 18lb. for a single piece weighing but 90lb.), its texture had not received the smallest injury; so that in this respect my last experiment proved less expensive than the first, though both together cost me nearly 30*l.*

As this murio-nitrate of tin, though exempt from the defects of the muriatic solution, had failed through others of a very opposite nature, I was induced to mix much greater proportions of nitric with the muriatic acid for dissolving tin, in order to see how much of the former could be used in this way, without so far yellowing the cochineal crimson as to preclude the use of any of the quercitron yellow in the dying of scarlet, an effect which I still expected from the nitric acid, when used in a very large proportion; but, to my great surprize, I could discover no such effect, even when I had dissolved the metal in nitric acid *alone.* At first I suspected some impurity in the acid which had

made, and in conjunction with the tartar, which was omitted in the former: but I will endeavour to ascertain the truth on this point by future trials with the same solution, after it has been kept during various longer periods, and also with and without the co-operation of tartar, and mention their results in a postscript to my second volume.

been employed; but having procured a fresh supply, and ascertained its purity by the proper means, I still found that tin dissolved by it had not the least tendency to change the cochineal crimson towards a yellowish or scarlet hue; and *that this effect, in the usual way of dying that colour, resulted wholly from the tartar*, (acidulated tartrite of pot-ash,) *which is always employed at the same time.* This fact I ascertained by repeated and varied experiments, in which I constantly found that cochineal, with the dyers' common solution of tin, and even with that made by nitric acid only, would produce nothing but a crimson without tartar; and that cochineal, *with tartar*, would produce *a scarlet*, not only with these last-mentioned solutions, but also, *and equally well*, with *the muriatic solution of that metal;* and therefore, that every thing which had been taught and believed to the contrary was repugnant to truth. And here I cannot conceal my wonder, that an error of so much consequence, and so destitute of all foundation, should have been propagated and confirmed by so many acute reasoners and sagacious observers in other respects; for, besides those eminent writers already mentioned, Mr. Pœrner has more recently adopted and propagated the same error, after making a great number of experiments, several of which, if they had been duly considered, would have

taught him the truth on this subject.* This also was even more lately done by M. Berthollet, in his Elémens de l'Art de la Teinture, where, to adopt the words of Dr. Hamilton's Translation, he says, "Tartar, as we have seen, gives a *deeper* and *more rosy hue* to the colouring matter of cochineal, precipitated by the solution of tin. It moderates the action of the nitro-muriatic acid, which tends to give scarlet an orange cast, though this orange cast is not to be seen in the precipitate produced by the solution of tin, which is on the contrary of a fine red. It is probable that the solution of tin gives scarlet an orange tinge, by means of the action the nitro-muriatic acid exerts on the wool, which, as well as all other animal substances, it has the property of turning yellow."†

"Thus (adds he), by putting more of tartar into the reddening, a deeper and fuller scarlet may be obtained; and on the contrary, the scarlet may be rendered more inclining to orange by omitting this ingredient." And he concludes the chapter by repeating this doctrine.

Here then it is manifest, that the nitro-mu-

* See Instruction sur l'Art de la Teinture, &c. à Paris, 1791.

† It is true that nitric acid alone makes wool, &c. yellow, but wool or cloth, boiled with nitro-muriate of tin, as a preparation for scarlet, remains perfectly white, if no colouring is mixed with it, as is well known.

riate of tin and the tartar are each supposed to produce effects *directly contrary to those which are really produced* by them, the effects of each being ascribed to the other; a mistake capable of producing much disappointment and detriment.*

* M. Berthollet, with his usual and becoming *candour*, has, in the *last* edition of his Elements, &c. admitted the *error* into which he had fallen, in common with all others, on this subject, and the truth of my observations respecting it. " On avoit, (says he) dans la première édition de ces élémens, attribué au tartre la propriété de donner une nuance plus foncée et plus rosée aux parties colorantes de la cochenille: cette opinion pouvait même être regardée comme générale; *mais Bancroft l'a combattue avec raison:* il prétend que si l'on supprime le tartre, on a une couleur cramoisie; que le tartre donne naissance à un tartrite d'étain insoluble, qui fait avec la cochenille une couleur jaune; que l'écarlate ordinaire est un mélange d'un quart de cette couleur jaune et de trois quarts ou un peu plus de la couleur cramoisie que donne la cochenille avec la dissolution d'étain," &c. And after mentioning my proposal for obtaining the yellow part of the scarlet colour from the quercitron bark, rather than from cochineal, he gives an account of three experiments which he had made by dying cloth with cochineal and a solution of tin; for two of which he also employed tartar in the ordinary, and in a double proportion: and he found that in proportion to the quantity of tartar employed, the colour inclined to the yellow tint, whilst that without tartar "avoit couleur *vineuse* et moins vive," &c. He adds, " *il est donc vrai* que le tartre fait incliner *au jaune* la couleur de la cochenille, et qu'il produit d'autant plus cet effet, que la proportion en est plus grande," &c. Elémens, tom. ii. p. 179, 180.

I must observe, however, that the explanation here given by M. Berthollet, of my conclusions in regard to the effects of

Having made myself certain that the dyers' spirit, or nitro-muriatic solution of tin, without tartar, would only dye a crimson with cochineal, I was induced to make an experiment therewith, instead of the muriate of tin, at the dye-house of the late Mr. Seward, in Goswell-street, and with views similar to those which directed the experiments before made at the dye-house of Messrs. Goodwin and Co. A piece of baize was accordingly boiled one hour and a quarter with the usual portion of nitro-muriatic solution of tin, (which had been prepared by Mr. Seward,) and with about one-fortieth of its weight of quercitron bark, without any tartar: After which it was taken out dyed of a bright yellow, though paler than it

tartar in the dying of scarlet, is not quite correct. I have never intended to decide, that the acid of tartar formed an *insoluble* tartrite of tin, and that this tartrite changed the colour of a *part* of the cochineal to a pure yellow, and thereby gave to the other part a *scarlet* tint; though I have in fact supposed this as an *ultimate* effect to result from the action of tartar. But I intended to leave it undecided, whether the acid of tartar acted conjointly with the other acids and the tin, or separately with the metal, in producing a scarlet instead of the *rose* colour, which would have been produced without it; and though I supposed the amount of this change to be equivalent to a conversion of nearly one-fourth of the cochineal colour to *a yellow*, yet I did not assume that the change in question had been operated or effected in a *fourth* or any other part *exclusively*, rather than on the whole collectively. Indeed, I have never found the *tartrite* of tin, even when employed *alone* with cochineal, able to render the colour *yellow*, though it produces a very *yellowish* scarlet.

would have been with the muriate of tin. The baize being rinced, and the dying vessel emptied, and then filled a second time with clean water, about four-fifths of the cochineal usually employed for the like quantity of baize, and a farther suitable proportion of the solution of tin, were put into it, and the baize being dyed therein, as usual, took what was allowed to be a good scarlet. Mr. Seward, however, did not seem so fully convinced, as I had expected, of the advantage of compounding a scarlet in this way from the cochineal crimson and quercitron yellow; and probably the experiment had not been attended with any very manifest success, or saving of cochineal, because the nitro-muriatic solution of tin which had produced but a pale yellow with the quercitron bark, had also acted more feebly in raising or exalting the cochineal colour than it usually does when assisted with tartar, which consists of a portion of vegetable alkali combined with an excess of its own peculiar acid; and therefore, whenever it is mixed with a solution of tin by any of the mineral acids, the tartar will be decomposed; because the mineral acids, by their superior attraction for, will unite with its alkaline basis, and disengage an additional portion of the tartarous acid, which will then unite with the metallic oxide, previously abandoned by the mineral acid, and thus pro-

duce a *tartrite of tin*, which last, in the usual way of dying scarlet, inclines the cochineal crimson to the yellow tint, and at the same time, (as I have since found,) exalts its colour more than the nitro-muriatic solution of tin alone would be able to do; and it is only this decomposition of the tartar, that has obviated the ill effects which otherwise must have resulted from the sulphuric acid, frequently contained in the common aqua-fortis used by the scarlet dyers.*

* This statement, first made in 1794, respecting the effects of tartar with sulphuric acid; is partly erroneous, or liable to misconception: wherever that acid (the sulphuric) acts upon tin, either *alone*, or with any mixture containing *nitric* acid, the oxide of that metal, probably by too much oxygenation, is brought into a state which renders it incapable of producing with cochineal any thing better, or approaching nearer to scarlet than an orange, or at most a *high salmon colour*. It is true indeed, that if oil of vitriol, be put either into the scarlet dying, or the preparation liquors, immediately after, or conjointly with the tartar, *it will do no harm*, provided the quantity be only sufficient to *decompose the tartar, and neutralize* its alkaline part. But as no tartar is employed by the dyers in making their ordinary solution of tin, and as the aqua-fortis used for that purpose, frequently contains a little sulphuric acid, the latter will have produced all its mischievous effects upon the tin, previously to the dying operation, and these effects will not afterwards be overcome by the tartar employed in that operation. Fortunately, however, the mischief which might be produced by a little sulphuric acid mixed with the aqua-fortis employed by the dyers to dissolve their tin, is commonly *obviated*, without their being sensible of it, by their practice of making a nitro-muriatic acid, not

Though I had hitherto failed in my endeavours to compose a scarlet colour with advantage, so as to save that part of the cochineal which appeared to be misapplied, by being yellowed in the usual process, I had nevertheless full confidence in my former reasoning on this subject, and employed myself from time to time in searching after more suitable means for attaining this end. Some of my earliest experiments with a solution, or rather a calcination of tin by the sulphuric acid, had shewn me that this preparation was very unsuitable for my purpose, because it really exerted a destructive action on the cochineal colour, by reducing it from a crimson down to a kind of salmon colour, which indeed was the highest colour produced on cloth by dying it with cochineal and sulphate of tin; I therefore discarded the use of sulphuric acid for dissolving tin, until particular circumstances led me some time after to dissolve a portion of it by the muriatic acid, combined with about one-fourth of its weight of oil of vitriol; and by trying this solution, I found that it produced very good

by mixing the muriatic *simply* with the nitric acid, but by adding to the latter a portion either of sea-salt, or of muriate of ammonia, either of which affords an alkali, which, by its stronger affinity for the sulphuric, than for either the nitric or muriatic acids, combines with and neutralizes the former, when the quantity is not too great, and thus renders it harmless.

effects in dying, without any appearance of that corrosive property which had acted so mischievously in the experiments made with tin, dissolved by muriatic acid only. I was therefore encouraged to make and try other solutions of that metal, by the same acids, united in various proportions; and have at length found reason to prefer a solution made by dissolving after the rate of about fourteen ounces of tin in a mixture of two pounds of oil of vitriol, (of the usual strength,) with about three pounds of muriatic acid. That which I have used was of the specific gravity of nearly 1170, and strong enough, with a sand-heat, to dissolve one-third of its weight of tin. The muriatic acid should be first poured upon a large quantity of granulated tin, in a capacious glass receiver, and the oil of vitriol afterwards added slowly; and these acids being mixed, should be left to saturate themselves with tin, which they will do in a longer or shorter time, according to the temperature of the atmosphere, without any artificial heat; but the solution may be rapidly promoted by a sand heat.

This solution contained but little more than half as much tin as the muriatic solution which had been used in the first experiment made at the dye-house of Messrs. Goodwin and Co., yet the metallic part of it existed in a state so much

more suitable for the purposes of dying, that a given quantity of it would produce much better effects than a like quantity of muriatic solution, containing nearly twice as much of the metal, and without any corrosive property, capable of doing the least mischief, unless used in much greater proportions than ever can be wanted for dying.*

The murio-sulphuric solution of tin, made in these proportions, will be perfectly transparent and colourless; and will probably remain so for many years, without becoming turbid, or suffering by any precipitation of the metal; at least, none has appeared in some which I have kept for more than three years. It will produce full twice as much effect as the dyers' spirit, or nitro-muriatic solution of tin, with less than a third of the expence. It has, moreover, the property of raising the colours of, I believe, all adjective dyes, more than the dyers' spirit, and full as much as the tartrite of tin, without changing the natural crimson of cochineal towards the yellowish hue; and, therefore, after

* Since my first edition of this volume was published, I have ascertained that even the proportion of tin here mentioned is unnecessarily great, and that equally good effects may be obtained with the same quantity of acids, when the latter contain but little more than half the quantity of tin which they are capable of dissolving.

having made a great number of experiments with it, I think myself warranted in strongly recommending this murio-sulphate of tin for dying the compound scarlet colour already described, (with the cochineal crimson and quercitron yellow,) for which it will be found highly effectual and œconomical.

For this species of scarlet nothing is necessary but to put the cloth, suppose 100lb. weight, into a proper tin vessel, nearly filled with water, in which about eight pounds of the muriosulphuric solution of tin have been previously mixed, to make the liquor boil, turning the cloth as usual through it, by the winch, for a quarter of an hour; then turning the cloth out of the liquor, to put into it about four pounds of cochineal, and two pounds and a half of quercitron bark in powder, and having mixed them well, to return the cloth again into the liquor, making it boil, and continue the operation as usual until the colour be duly raised, and the dying liquor exhausted, which will be the case in about fifteen or twenty minutes; after which, the cloth may be taken out and rinced as usual. In this way the time, labour, and fuel, necessary for filling and heating the dying vessel a second time, will be saved; the operation finished much more speedily than in the common way; and there will be a saving of all the tartar, as well as of two-thirds of the

cost of spirit, or nitro-muriatic solution of tin, which for dying 100lb. of wool, commonly amounts to 10s.; whereas, 8lb. of the murio-sulphuric solution will only cost about 3s. There will be, moreover, a saving of at least one-fourth of the cochineal usually employed, (which is generally computed at the rate of one ounce for every pound of cloth,) and the colour produced will certainly not prove inferior in any respect to that dyed with much more expence and trouble in the ordinary way. When a rose-colour is wanted, it may be readily and cheaply dyed in this way, only omitting the quercitron bark, instead of the complex method now practised of first producing a scarlet, and then changing it to a rose by the volatile alkali contained in stale urine, set free or decomposed by pot-ash or by lime: and, even if any one should still *unwisely* choose to continue the practice of dying scarlet without quercitron bark, he need only employ the usual proportions of tartar and cochineal, with a suitable quantity of the murio-sulphate of tin, which, whilst it costs so much less, will be more effectual than the dyers' spirit.*

* The murio-sulphate of tin here recommended, is now employed by the dyers in many parts of England, particularly in Yorkshire and Lancashire, though many of them do not know how, or with what acids it is prepared. A considerable distiller of aqua-fortis, and of muriatic acid, who also prepares solutions

Several hundreds of experiments warrant my assertion, that at least a fourth part of the cochineal generally employed in dying scarlet, may be saved by obtaining so much yellow as is necessary to compose this colour from the quercitron bark; and indeed nothing can be more self-evident, than that such an effect, *ceteris paribus*, ought necessarily to result from this combination of different colouring matters, suited to produce the compound colour in question. Let it be recollected that the cochineal crimson, though capable of being changed by the acid of tartar towards the yellow hue on one hand, is also capable by different means of being changed towards a blue on the other, and of thereby producing a purple without indigo or any other blue colouring matter: yet I am confident that

of tin in large quantities, informs me that he is in the practice of selling this preparation of that metal, *under another denomination*, and that it is chiefly employed to dye the most vivid and beautiful yellows from quercitron bark. It has also been of late used to dye scarlet with a preparation called lac lake, made (in the East Indies) from the stick lac, to be noticed in my next chapter.

Mr. Hawker (near Stroud, in Gloucestershire,) lately mentioned at p. 454, told me, in 1795, soon after the publication of my first edition, that he had prepared the murio-sulphate of tin, according to my direction, and found it answer the purpose for which it had been recommended by me.

nobody would believe a pound of cochineal so employed, capable *alone* of dying as much cloth, of any particular shade of purple, as might be dyed with it, if the whole of its colouring matter were employed solely in furnishing the crimson part of the purple, whilst the other (blue) part thereof was obtained from indigo. To say that a pound of cochineal *alone* could produce as much effect or colour as a pound of cochineal and a pound of indigo *together*, would be an improbability much too *obvious* and *palpable* for human belief; and there certainly would be a similar improbability in alleging, that a pound of cochineal, employed in giving another compound colour (scarlet), could alone produce as much effect as a pound of cochineal and a pound of quercitron bark, when the colour of this last was employed only in furnishing one of the component parts of the scarlet, for which a considerable portion of the colouring matter of the cochineal must otherwise have been expended, which certainly happens in the new mode of dying scarlet, because the colour produced with an addition of the quercitron yellow inclines no more towards a yellow, than the scarlet produced by yellowing a part of the cochineal colour in the usual method with tartar. I retain, therefore, at this moment, as much confidence as I ever had in the reality

and importance of my proposed improvements in this respect.*

The scarlet composed of cochineal crimson and quercitron yellow, is moreover attended with this advantage, that it may be dyed upon wool and woollen yarn, without any danger of its being changed to a rose or crimson, by the process of fulling, as always happens to scarlet dyed by the usual means. This last being in fact nothing but a crimson or rose colour, yellowed by some specific or particular action of the acid of tartar, is liable to be made crimson again by the application of many chemical agents, (which readily overcome the changeable yellow produced by the tartar,) and particularly by calcareous earths, soap, alkaline salts, &c. But where the cochineal colouring matter is applied and fixed merely as a *crimson* or *rose* colour, and

* Of the benefit which I formerly expected to obtain by employing pot-ash or soda to extract a part of the cochineal colour, which water alone did not appear capable of extracting, it must be remarked, that I have some time since convinced myself of its being an illusion; for, by repeated trials, I have found that the solid parts of powdered cochineal remaining after it has been boiled with the solution of tin and tartar, as in the common dying process, yield no colour worthy of notice, upon the application of pot-ash; the solution of tin and tartaric acid, enabling the water to extract the colour sufficiently; so that in truth there is no such waste of cochineal colour as I had supposed, in the usual way of employing that drug.

is rendered scarlet by superadding a very *permanent quercitron yellow,* capable of resisting the strongest acids and alkalies, (which it does when dyed with solutions of tin,) no such change can take place, because the cochineal colour having never ceased to be crimson, cannot be rendered more so, and therefore cannot suffer by those impressions or applications which frequently change or spot scarlets dyed according to the present practice.*

There is also a singular property attending the compound scarlet dyed with cochineal and quercitron bark; which is, that if it be compared with another piece of scarlet dyed in the usual way, and both appear by day-light *exactly of the same shade,* the former, if they be afterwards compared by candle-light, will appear to be at least several shades higher and fuller than the latter; a circumstance of some importance, when it is considered how much this and other gay colours are generally worn and exhibited by

* MM. Thenard and Roard, in their "Mémoire sur les mordants employés dans la teinture," observe, that ever since the discovery of scarlet, its liability to become crimson has been *complained of, without any attempt to ascertain and obviate the cause of that defect.* In making the latter part of this observation, they must surely have forgotten, or never have been made acquainted with this part of my publication, which had preceded their Memoir sixteen years.

candle-light during a considerable part of the year.

To illustrate more clearly the effects of the murio-sulphuric solution of tin with cochineal in dying, I shall state a very few of my numerous experiments therewith; observing, however, that they were all several times repeated, and always with similar effects.

1st. I boiled one hundred parts of woollen cloth in water, with eight parts of the murio-sulphuric solution of tin, during the space of ten or fifteen minutes; I then added to the same water four parts of cochineal, and two parts and a half of quercitron bark in powder, and boiled the cloth fifteen or twenty minutes longer; at the end of which it had nearly imbibed all the colour of the dying liquor, and received a very good, even, and bright scarlet. Similar cloth dyed of that colour at the same time in the usual way, and with a fourth part more of cochineal, was found upon comparison to have somewhat less body than the former; the effect of the quercitron bark in the first case having been more than equal to the additional portion of cochineal employed in the latter, and made yellow by the action of tartar.

2d. To see whether the tartrite of tin would, besides yellowing the cochineal crimson, contribute to raise and exalt its colour more than the murio-sulphate of that metal, I boiled one

hundred parts of cloth with eight parts of the murio-sulphuric solution, and six parts of tartar, for the space of one hour; I then dyed the cloth, *unrinced*, in clean water, with four parts of cochineal, and two parts and a half of quercitron bark, which produced a bright aurora colour, because a double portion of yellow had been here produced, first by the quercitron bark, and then by the action of tartar upon the cochineal colouring matter. To bring back this aurora to the scarlet colour, by taking away or changing the yellow produced by the tartar, I divided the cloth whilst unrinced into three equal parts, and boiled one of them a few minutes in water, slightly impregnated with pot-ash; another in water with a little ammonia; and the third in water containing a very little powdered chalk, by which all the pieces became scarlet; but the two last appeared somewhat brighter than the first, the ammonia and chalk having each rosed the cochineal colour rather more advantageously than the pot-ash. The best of these, however, by comparison, did not seem preferable to the compound scarlet dyed without tartar, as in the preceding experiment; consequently this did not seem to exalt the cochineal colour more than the murio-sulphate of tin; had it done so, the use of it in this way would have been easy, without relinquishing the advantages of the quercitron yellow.

3d. I boiled one hundred parts of woollen cloth with eight parts of the murio-sulphuric solution of tin, for about ten minutes, and then added four parts of cochineal in powder, which by ten or fifteen minutes more of boiling, produced a fine crimson. This I divided into two equal parts, one of which I yellowed or made scarlet by boiling it for fifteen minutes with a tenth of its weight of tartar in clean water; and the other, by boiling it with a fortieth of its weight of quercitron bark, and the same weight of murio-sulphuric solution of tin; so that in this last case there was an addition of yellow colouring matter from the bark, whilst in the former no such addition took place, the yellow necessary for producing the scarlet having been wholly gained by a change and diminution of the cochineal crimson or rose colour; and the two pieces being compared with each other, that which had been rendered scarlet by an addition of quercitron yellow, was, as might have been expected, several shades fuller than the other.

4th. I dyed one hundred parts of woollen cloth scarlet, by boiling it first in water with eight parts of murio-sulphate of tin, and twelve parts of tartar, for ten minutes, and then adding five parts of cochineal, and continuing the boiling for fifteen minutes. This scarlet cloth I divided equally, and made one part crimson, by boiling it with a little ammonia in clean

water; after which I again rendered it scarlet, by boiling it in clean water, with a fortieth of its weight of quercitron bark, and the same weight of murio-sulphate of tin; and this last, being compared with the other half, to which no quercitron yellow had been applied, was found to possess the most colour, as might have been expected. A piece of the cloth, which had been dyed scarlet by cochineal and quercitron bark, as in the first experiment, being at the same time boiled in the same water with ammonia, did not become crimson, like that dyed scarlet without the bark.

In this way of compounding a scarlet from cochineal and quercitron bark, the dyer will at all times be able, with the utmost certainty, to produce every possible shade between the crimson and yellow colours, by only increasing or diminishing the proportion of bark. It has, indeed, been usual at times when scarlets, approaching nearly to the aurora colour, were in fashion, to superadd a fugitive yellow either from turmeric, or from what is called young fustic (rhus cotinus); but this was only when the cochineal colour had been previously *yellowed as much as possible by the use of tartar*, as in the common way of dying scarlet; and therefore that practice ought not to be confounded with my improvement, which has for its object to preclude the loss of any part of the

cochineal rose or crimson, by its conversion towards a yellow colour, which may be so much more cheaply obtained from the quercitron bark.

By sufficient trials, I have satisfied myself that the cochineal colours, dyed with the murio-sulphuric solution of tin, are in every respect at least as durable as any which can be dyed with any other preparation of that metal; and they even seem to withstand the action of boiling soap suds somewhat longer, and therefore I cannot avoid earnestly recommending its use for dying rose and other cochineal colours, as well as for compounding a scarlet with the quercitron bark.

Having ascertained about the time of the publication of my first edition of this volume, that the *red* colour afforded by madder, might be greatly *exalted* and *brightened* by employing it with the murio-sulphate of tin, and indeed, with the nitro-muriate and the muriate of that metal; (instead of alum) and that the *lively yellowish red* so produced, was *extremely durable*, it occurred to me, that there might be an advantage at least for ordinary scarlets, in substituting the *madder* for the quercitron bark, to compose a scarlet with cochineal, on the principle before explained; because the former might be made not only to supply the *yellow* part of the scarlet, but also a portion of *red*, *in aid* of the cochineal colour, without perceptibly detracting from the vivacity of the

latter;—with this expectation, I soon after made a great number of experiments, which fully answered my expectation, and proved by their general results, that cloth prepared by boiling the usual time with murio-sulphate of tin, (the acids not being saturated by the metal) and without tartar, and afterwards dyed with cochineal and the finest Zealand madder, in the proportion of from two to three or even four pounds of the latter, with one of the former, might be made to acquire a good scarlet, with a saving of one fourth or one fifth of the cochineal, which would have been necessary to produce it *alone*. When more of madder than the proportion just mentioned was employed, the colour, if *contrasted* with a *very fine* scarlet, appeared to incline towards a yellowish brown tint, though, to common eyes, this would be hardly perceived without such contrast. It must, however, be admitted, that for scarlets which are intended to *excel* and vie with those of Mr. Nash or his successor, it would be advisable to employ cochineal alone, or with the quercitron yellow instead of the madder red, cheapness being for them of less importance than beauty of colour. But for ordinary scarlets, I am convinced it may be employed as just mentioned, without any perceptible degradation of the colour, and with a considerable diminution of expence.

I have thus freely given the results of a multitude of experiments, on which I have expended money, with much more of time and meditation; and though some years may elapse before the truth and importance of what I here offer are fully recognized, I am confident this will happen sooner or later; and by putting it into every one's power to bring my ideas to the test of experience, I shall have at least done my duty.*

I had not particularly directed my attention to the dying of scarlet, until the year 1786, when no person, so far as I have been able to discover, had ever attempted to ascertain the effects of any solution or preparation of tin, excepting that with the nitric or nitro-muriatic acids upon the colouring matter of cochineal; and I shall therefore state the results of numerous experiments which I have since made, with that metal, differently combined, and at various degrees of oxidation, omitting all details respecting the proportions, and modes of conducting the dying operations, which are to be understood as having been conformable to

* A portion of yellow colouring matter, obtained either from the quercitron bark or the rhus cotinus, is now (1812,) very generally employed in this country with cochineal, for dying scarlet; not indeed, without tartar, but with a smaller quantity than that which is employed in other countries, and which was formerly employed in this.

the common practice, where nothing is mentioned to the contrary.

Woollen cloth, dyed with cochineal and pure nitrate of tin recently prepared, produced a fine crimson, and this, boiled in the same liquor with tartar, was changed to a good scarlet. A similar, but rather better effect was produced by tin dissolved immediately in a mixture of aqua-fortis and tartar. The scarlet given by this tartaro-nitrate of tin appeared highly beautiful.

Tin put into aqua-fortis, with a considerable portion of refined sugar, afforded a very thick adhesive solution, which assumed a blackish brown colour, like that of *burnt sugar*, and being tried as a mordant in dying, it was found incapable of fixing the cochineal or any other colours. The tin in this state did not seem fitted to combine with the fibres of the cloth, and the sugar had manifestly suffered a kind of combustion, having probably in this case produced, upon the tin, as it does with indigo, (see p. 217,) a *deoxygenating* effect. Spirit of wine, put with tin into aqua-fortis, also rendered the solution unfit to serve as a mordant, and, as I conclude, by a similar deoxygenation.

Tin, granulated and calcined with an equal quantity of salt-petre in a red-hot crucible, being thrown into water, afforded a milky solution, tasting very sensibly of the alkaline part of the salt-petre, and evidently suspending a

considerable portion of the metallic calx. Cloth boiled in water with some of this solution, then rinced, and dyed with cochineal, took a crimson, inclining to the purple; and this, boiled in the same liquor with tartar, was changed to scarlet.

Having poured two pounds of aqua-fortis, with an equal weight of water, upon a large quantity of granulated tin, and left them together during the three summer months of 1790, I afterwards found near a pound of the calx of tin collected in solid lumps at the bottom of the glass vessel. This being separated and dried, some of it was finely powdered and *thoroughly washed*; and being put with an equal weight of cochineal into water, I boiled cloth therein, which took a full equal crimson, somewhat deficient in brightness.* Tartar being added to the liquor, and the cloth farther boiled therein, it acquired a good scarlet. Lemon juice used, instead of tartar, produced the like effect. By substituting caustic volatile alkali for tartar and lemon juice, a crim-

* The calx or oxide of tin employed for this experiment, was some of that which is mentioned at pages 214 and 215, as having efficaciously *de*oxygenated indigo: consequently it was far from being in the state of a peroxide, or at the maximum of oxygenation; in which state I consider tin as being incapable of producing with cochineal any thing more red or elevated than an orange, or a salmon colour, at the most.

son, greatly inclining to purple, was produced. The oxide of tin, therefore, does not act in all cases *merely as such,* but its effects often depend on triple, quadruple, and sometimes even more complex combinations, in which different saline and other parts of the compound remain permanently united, at least where the shades of colour depending on them are found permanent. It is thus that sea-salt, and other purely saline matters, which, having no earthly or metallic basis, cannot become the basis of any adjective colour, produce *lasting* effects in modifying and varying the shades of different colours.*

It must, however, be observed, that though the calx of tin, just mentioned, was, after being thoroughly washed and dried, capable of dying a crimson on woollens with cochineal, and a scarlet, where either tartar, lemon juice, or Quercitron bark were added, it would not permanently combine with, or become the basis of,

* Hellot describes, at p. 234, a " *Cramoisi de Languedoc,*' which was dyed with cochineal upon cloth prepared as for the scarlet dye, excepting, that instead of tartar, sea salt was added to the solution of tin; which addition caused the colour to incline towards the purple or dark crimson; an effect which all the mineral acids seem to produce with cochineal, when neutralized by soda, and more especially by potash; and therefore, in making the common dyers' spirit, when nitric and muriatic acids, *perfectly free* from the sulphuric, can be had, it would be better to employ the muriatic acid instead of sea salt, especially when very bright scarlets are wanted.

these colours upon cotton; and indeed, on woollen it was only the finer particles of the calx which really combined with the colouring matter and the wool, the grosser being always distinctly found at the bottom of the dying vessel; and when I attempted to impregnate woollen cloth with this oxide of tin only by boiling them together, I always found, on rincing the cloth, and endeavouring to dye it with cochineal in a different vessel or bath, that the oxide had not penetrated or united with the wool, so as to afford a basis for raising and fixing the colour, it being necessary for this purpose, that both the oxide and the colouring matter should be mixed together in the dying vessel, and exert their mutual attractions for and upon each other, before they could be properly taken up by the cloth; and this was done better after they had been previously mixed and left together for several hours.

One ounce of the calx of tin before mentioned, unwashed, being dissolved in three ounces of muriatic acid, and woollen cloth being dyed with a tenth of its weight of this solution, and a twentieth of cochineal, it took but a very languid colour. The oxide of tin, (probably from too much oxidation) being immediately decomposed upon its intermixture with water, and manifesting very little disposition to penetrate or combine with the fibres of the wool; so that after long boiling, a great

part of it, and of the colouring matter, remained suspended in the dying liquor, as in my second experiment at the dye-house of Messrs. Goodwin and Co.

Cochineal with a solution of tin by muriatic acid only, dyed a beautiful crimson or rose colour; and with a solution of that metal, by a mixture of tartar and muriatic acid, a beautiful scarlet.

Cochineal, with tin dissolved by a mixture of muriatic, and pyroligneous acid, produced a dark crimson; and with tin, and a little manganese dissolved in muriatic acid, it produced a very bluish crimson.

Cochineal, with tin dissolved by muriatic acid and borax mixed, dyed a very good crimson.

Cochineal, with tin calcined by the long continued action of sulphuric acid, dyed a salmon colour; and with a recent solution of tin, it produced a reddish salmon colour, inclining a little to the crimson. A like colour was produced with tin dissolved by equal parts of sulphuric and nitric acids mixed.

Oil of vitriol, having been poured upon tartar and granulated tin, the mixture immediately became black, by the action of the sulphuric acid upon the carbonic basis, which, with hydrogene and oxygene, are the constituents of tartar. Cloth, dyed with a tartaro-sulphuric solution of tin thus made, and cochineal, took an aurora colour.

Tin dissolved by the pure acid of tartar, separated from its alkaline basis, (by the means usually employed for that purpose,) dyed with cochineal on cloth a very lively and beautiful scarlet, inclining a little to the orange. A similar colour was produced by water saturated with cream of tartar, in which granulated tin had been kept six weeks.

Tin may be readily dissolved by pure citric acid, and more slowly by lemon juice; and the solution newly made, dyes, with cochineal, a most beautiful scarlet, inclining, like the preceding, a little to the aurora. Indeed, I have repeatedly found, that the citric acid with tin, acts at least as efficaciously as that of tartar in yellowing the cochineal crimson. Nothing can exceed the beauty of scarlet dyed with the citrate of tin, and if it were not too *costly*, this solution would deserve the preference of every other for dying scarlet.

Granulated tin, dissolved by strong vinegar, acquired a milky appearance with a very particular, and somewhat of an unpleasant smell; and with cochineal it dyed cloth of a scarlet, inclining a little to the rose colour.

Tin dissolved by the pyroligneous acid produced with cochineal a colour between the scarlet and rose colour.

Phosphoric acid produced a permanently transparent and colourless solution of tin, which,

with cochineal, dyed a bright yellowish scarlet.

Tin, dissolved by fluoric acid, produced with cochineal a very bright scarlet.

In addition to this account of experiments made previously to my first publication on this subject, I will mention a few of those which I have since made.

Tin having been dissolved by a *direct* mixture of pure nitric and muriatic acids, in equal proportions, the former of the specific gravity of 1500, and the latter of 1170, this solution, with cochineal and the common allowance of tartar, produced a very bright lively scarlet.

Tin, having been dissolved by a similar mixture, with an addition of sulphuric acid, equal to one fourth of the nitric, and the solution being afterwards employed with cochineal and tartar, as in the last-mentioned experiment, a salmon colour only was produced.

Tin, being dissolved in a mixture similar to that last-mentioned, but with this difference, that *before* the sulphuric acid was added, tartar, amounting to three times the weight of the sulphuric acid, had been mixed with the nitric and muriatic; and this solution being employed with cochineal, and a little more tartar, a good scarlet was produced; the tartar which had been added *before* the sulphuric acid having, by its alkaline part, neutralized the vitriolic acid, and obviated

the evil produced by the latter, in the preceding experiment.

Having precipitated the oxide of tin (by soda) from the common dyers' spirit, or nitro-muriate thereof, and subjected this to the action of sulphuric acid, I found it incapable, with cochineal, of dying any colour more elevated than the *orange*.

After this account of the effects of the oxides of tin, in various states and combinations, when applied with cochineal on wool or woollen cloths, it is, I think, expedient for me to add a few other observations concerning those particular solutions of that metal, which are most frequently employed as mordants in dying, and the means by which they may be most advantageously obtained and employed.

It can hardly be necessary to premise, that for these solutions, the *purest* tin should always be selected; such as that of *Malacca*; next to which is that of Banca; and after it, the tin of Mexico, is considered as most pure. In regard to the tin mines of Europe, those of Cornwall afford tin of the greatest purity; and after these, the tin of Bohemia is considered as preferable to that of Saxony.

The most frequent adulterations of tin are produced by intermixtures of arsenic, lead, copper, and iron. The first of these renders tin whiter and more brittle; the others give it shades of grey, which are dark, when either of

the *two* last bears a considerable proportion. The means of detecting these adulterations have been mentioned by most of the systematic chemical writers. The presence of either iron or copper in tin, may be readily ascertained by dissolving a little of it in pure muriatic acid, and dropping the solution into a prussiate of lime, which will afford a precipitate more or less *blue*, if the tin contains iron; and if it contains copper, a *reddish bronze* precipitate.

When pure colourless nitric and muriatic acids are mixed in quantities not very disproportionable, the former of these acids will be partially decomposed, with an exhalation of oxymuriatic acid, and a production of nitrous gas; but this last will remain for some time dissolved by the mixed acids, and give the mixture a red colour; and if granulated tin be added to the mixture, it will soon destroy this red colour, by expelling the nitrous gas; and will, moreover, cause a farther decomposition of the nitric acid, by combining with its oxygene; which combination renders it susceptible of a more speedy dissolution by the muriatic part of the compound.

Dyers, however, do not commonly produce their aqua-regia by a simple mixture of the nitric and muriatic acids, but by adding to single aqua-fortis a portion of sea salt; and in so doing they (without knowing it) obviate the injury which the small proportion of sulphuric acid

frequently contained, either in aqua-fortis or in muriatic acid, would produce, if allowed to act upon tin *in conjunction with nitric acid*; as I have found by numerous experiments. But in this way of producing a nitro-muriatic acid, the soda contained in the sea salt, by combining with the sulphuric acid, and forming Glauber's salt, renders the latter incapable of any hurtful action; at least, if there be not more of it than the soda of the sea salt can neutralize; and when this happens, the addition of a little salt petre, which Hellot and others have thought beneficial, (without assigning any reason for thinking so), would render this excess of sulphuric acid harmless, by affording potash to form with it a sulphate thereof.

By modern chemists, the solution of tin, when made by nitro-muriatic acid, is supposed to contain, or afford, only a *muriate* of that metal; it being assumed, that the nitric acid suffers a *complete* decomposition, and that its oxygene is *all*, either expended to oxidate the metal, or exhaled with the nitrous gas. I believe, however, that the nitric acid is *never completely decomposed*, by this operation;* at least I have

* The proportion of either sea salt or muriate of ammonia, employed by scarlet dyers in making their ordinary solution of tin, is by much too small to permit us to believe the result of that process to be merely a *muriate*. Hellot, who prefers a muriate of ammonia to sea salt, prescribes as the *best* propor-

never found any solution of tin made by nitro-muriatic acid, which did not differ considerably in its *sensible* qualities, and also in its effects, as a mordant, with cochineal, &c. from a solution of that metal by pure muriatic acid. I attach no importance to the *straw, or amber*, colour of the solution of tin, commonly employed by the dyers, while the muriate of tin *is colourless*; because the colour of the former certainly results from the neutral salts which it holds dissolved; for, when the solution is made by a *direct* mixture of pure nitric and muriatic acids, it is as colourless as if it had been made by muriatic acid only; but in this case, it invariably exhales, and for a long time, the odour of nitrous gas, even when the acids were mixed in equal proportions; a certain proof, that the nitric acid was at most but partially decomposed.

It has, moreover, several other peculiarities,

tion, only half as much of it in weight, as of the metal employed; and Dambournay used a proportion smaller than Hellot's, which, however, is I believe, that of most of the dyers, whether they employ sea salt, or sal ammoniac; and certainly neither of these could afford muriatic acid sufficient to dissolve *twice its weight of tin*, as it must do, if the solution so produced were *merely a muriate* of that metal. I have sometimes employed a solution of tin, made by a diluted, but very pure nitric acid, with an addition of muriate of ammonia, amounting *to no more than one eighth* of the weight of metal so dissolved, which could have contained but a small proportion of muriate of tin; but this solution in a very few days, will lose its transparency, and be capable of producing *only* orange salmon colours.

particularly that of not affording *crystals* by evaporation, like the muriate of tin, and also that of becoming both opaque and gelatinous by keeping, which does not happen to the muriatic solution; nor does it, when used in *excess*, injure the texture of wool, so much as an equal *excess* of the latter.

One cause of this *last* peculiarity, or difference, may depend upon the *production of ammonia*, whenever tin is dissolved by nitro-muriatic acid. Berthollet obtained satisfactory evidence of the reality of this production, even when the aqua-regia was made by a direct and gradual mixture of the pure nitric and muriatic acids; and he considers it as being a fact, which may enable us to understand, why in dying there is less difference than might be expected, between the effects of a solution of tin, made by this direct and simple mixture of the two acids, and those of a solution made by aqua-fortis with an addition of muriate of ammonia.

Besides this production of ammonia, M. Berthollet supposes, that *another* occurs in the dying operation, whenever the heat is near the boiling point: and that, by this, and the former production of ammonia, the acidity of the solution of tin is greatly diminished; which, as he thinks, will enable us to understand why the cloth is not injured by the common process for dying scarlet, though the *nitric* acid of *itself*, would, even when much diluted, produce hurtful effects

upon it; and he also considers this as explaining the cause of the injury which the cloth suffered in my *first* experiment at the dye house of Messrs. Goodwin and Platt.*

Having ascertained, as is mentioned in the note to p. 462, that a muriate of tin, containing only half the quantity of that metal, which the acid might have been made to dissolve, had operated as efficaciously as an equal quantity, containing twice as much tin, and in some respects with a better effect, in the dying of scarlet, I was led by this and other facts to suspect, that a much smaller proportion of tin than that which the dyers commonly dissolve in their nitro-muriatic acid, would produce equally beneficial effects. And, to ascertain the truth on this point, I put two drachms of powdered muriate of ammonia, into three ounces of strong nitric acid of the specific gravity of nearly 1500; and, having diluted this mixture by adding to it six ounces of water, I made it gradually dissolve fine granulated tin, until the acid was completely saturated; when

* After mentioning the neutralizing, or saturating effect of the ammonia, formed and acting, as has been just stated, M. Berthollet adds "on trouve encore dans cette action *saturante* l'explication d'une observation de *Bancroft*. Il vouloit substituer dans la teinture del'ecarlate, le muriate, d'Etain,au nitro-muriate; mais, il en fallut une plus grande proportion, et la laine se trovée fort déteriorée. Dans cette operation, il ne pouvait se former de l'am moniaque, et l'acide muriatique, que affaiblit facilement la laine, exerçait sur elle toute son action." Elemens, &c. tom. i, p. 385.

I found that the tin so dissolved amounted in weight to a little more than half the weight of the nitric acid. On the same day I made another solution, similar in every respect to the first, excepting only that the tin dissolved therein weighed only half as much; and with these solutions, I made several experiments, the two following days, which were afterwards repeated, and in all of them I found, that the solution containing *only half* of the tin, which might have been dissolved therein, produced with cochineal, colours which *at least* were in every respect as good as those resulting from an equal quantity of the saturated solution; and after I had ascertained by several trials the smallest proportion of the half saturated solution of tin which was necessary to produce a good scarlet upon a given weight of broad-cloth, I found, that the *saturated* solution would only produce an *inferior* colour, when (on account of its greater proportion of tin) I diminished the quantity even but an eighth part. I conclude, therefore, that nearly one half the tin, which the scarlet dyers commonly dissolve with aqua-fortis, and a little sea salt, to make what they denominate *spirit*, is *wastefully* employed; a fact which, considering the increased price of tin, may, by proper attention, produce a saving of very considerable importance. It appears to me, indeed, from a variety of considerations, that a proportion, and not a small one, of superfluous *or unsaturated* acid, is highly

useful to enable the basis, or oxide of tin, actually employed, to produce its *utmost* and *best* effect, by conveying it more *copiously* and thoroughly, or with greater *penetration*, into the substance of the wool or cloth. For, with this superfluous acidity, I have repeatedly made the scarlet dye penetrate completely the *innermost* parts of the cloth, without any of the means mentioned in a note at p. 91, as having been employed by Mr. *Nash*, and his successor, for this purpose, and without any other means excepting the use of a superfluous acidity; and I think one of the benefits resulting from the employment of tartar, either with alum or with the solutions of tin, is that of furnishing a portion of uncombined acid, *in addition* to that which accompanies the alluminous or metallic basis; which basis, being thereby enabled to penetrate wool or cloth more intimately, afterwards attracts the colouring matter more copiously and thoroughly. It must however be observed, that this *superfluity* of acids may be too great; and that it should never be employed in the *same bath*, or liquor, which contains the cochineal, but always in the previous boiling; since all acids, when present in a large proportion, weaken or render *latent* the colour of that insect.

In regard to the *muriate of tin*, I may be allowed to premise, that the muriatic acid, in its liquid state, is necessarily combined with water; and that the proportion of the latter, in which

the acid is best preserved, and most commonly sold, is such as to render its specific gravity equal to 1160, or at most 1170; and that, when of the latter degrees of strength, three pounds of it will dissolve nearly one pound of granulated tin, with the assistance of a sand heat.

When *pure*, the muriatic acid is colourless; though it frequently exhibits a light straw colour, resulting, as is supposed, from a small portion of iron dissolved by it: but this disappears almost instantaneously, if a little tin be dropped into the acid.

The dissolution of tin by this acid, is always accompanied by a copious emission of *bubbles*, which, excepting a little of the acid escaping at the same time, appear to consist of *hydrogene*, disengaged, as has been generally believed, in consequence of a decomposition of the water previously united to the acid; which decomposition is supposed to afford oxygene sufficient to oxidate the metal, as far as is necessary to render it soluble by the muriatic acid. Davy, however, in reviving the doctrine of Scheele, endeavours to maintain, that the muriatic acid itself contains hydrogene, which, by this operation, is set free, while that, which he supposes to be its elementary part, and which he denominates *chlorine*, dissolves and combines with the metal. (See Phil. Trans. for 1810).

Having already, in the introductory part of

this volume, stated every thing which I mean to suggest, on *this* intricate subject, I shall proceed to observe, that however the emission of hydrogene may be explained, it is attended with a considerable escape of muriatic acid, which carries with it a portion of the metal itself, as is manifested by the smell. Gay Lussac considers himself as having ascertained that tin, by being so dissolved, combines with 13,5 per cent. of oxygene; and that, by making a current of aqueous vapour pass over the metal, in a red heat, a white oxide may be produced, similar to that which is formed by subjecting tin to the action of concentrated nitric acid, and which, according to his experiments, consists of 27,2 parts of oxygene to 100 of tin. (See Ann. de Chimie, tom. 80, p. 169.)

Those who wish to dissolve large quantities of tin by muriatic acid, will find it advantageous to decompose the dry sea salt, by employing sulphuric acid in the proportion of five parts of the latter to eight of the former; using the precautions which have been prescribed, by chemical writers: and, by collecting the muriatic acid as set free in vapour, and conveying it immediately into large receivers, containing granulated tin with a little water, to absorb the dry acid vapour, the heat constantly and gradually evolved by that absorption, will (as M. Chaptal asserts) suffice to promote a solution

of the metal, without any expence of fuel. (See Chimie, appliqué aux Arts. tom. iv, p. 182.) In this way, also, the loss of acid, and of tin, by evaporation, may be in a great degree obviated; as indeed it may be when common muriatic acid is employed for this purpose, if the solution be made in tubulated retorts.*

If muriate of tin, containing one-fourth of its weight of the metal, be sufficiently evaporated, it will afford considerably more than half its weight of solid transparent crystals, which are the heaviest of all the metallic salts; but the evaporation is accompanied with a pungent disagreeable odour, produced by an intimate combination of muriatic acid and tin, which is highly volatile; and, consequently, the bringing such a solution into a crystallized form, must be attended with a great loss, both of the acid and the metal.

* Being at the house of Mr. Hawker, at Dudbridge, near Stroud, in Gloucestershire, during several of the last days of August, 1795, about 12 months after my first publication on this subject, that very estimable dyer informed me, that he had then lately begun to employ the muriate of tin for dying scarlet with good effect, and a considerable saving of expence in regard to the mordant; and he also shewed me the way in which his muriate of tin was prepared, which was, by putting large portions of the granulated metal into muriatic acid, contained in capacious, open vessels, and leaving it therein several weeks, assisted only by the ummer's warmth: a great evaporation and waste of acid unavoidably occurred, and the acid, as far as I could judge, was not more than half saturated; which doubtless was an advantage.

Tin when first dissolved by muriatic acid, is supposed to be at the lowest degree of oxidation, but if the atmosphere be allowed free access to the solution, it will constantly absorb and unite with an increased portion of oxygene; and Pelletier pretends, that in proportion as it does this, and becomes *most oxidated*, it also becomes most efficacious and useful as a mordant in dying.* But his experiments certainly do not warrant any such *general* inference; and the numerous trials which I have made of this metal as a *basis*, (with cochineal, quercitron bark, &c.) at various, and probably at all the possible degrees of oxidation,† have abundantly convinced me, that the oxide of tin acts most powerfully in exalting and giving vivacity to colours, when it is *but little* oxidated, and that every degree of oxygenation beyond a certain unascertained number, tends to reduce or diminish the *high*

* See Mem. et Observat. de Chimie. tom. i.

† I am aware that modern chemists are disposed to consider tin as only susceptible of two stages or degrees of oxygenation; the lowest called a *protoxide*, in which the metal contains about 13 per cent. of oxygene; and the highest called *peroxide*, in which, according to some estimations, it is at about 24 oxygene to 76 of tin, and, according to others, at 28 to 72. I believe, however, that in my experiments, I have employed this metal at several intermediate stages or degrees of oxydation, notwithstanding all that has been written, and particularly by Professor Berzelius, on the *determinate proportions* in which the inorganic elements of nature are supposed to unite.

red of the cochineal dye, and at the same time to make it incline to, or partake of, too much of the *orange*, so as only to produce, when highly oxidated, what I have denominated a salmon colour. Such is invariably, and in a remarkable degree, the effect of tin, when it has been subjected to the action of sulphuric acid alone, or in conjunction with the nitric; and also after it has been for some time rapidly dissolved by pure nitric acid but little diluted; and it can hardly be necessary for me to add, that in all these cases the metal will have obtained a higher degree of oxygenation. Similar effects, though in smaller degrees, have been found to result from a variety of combinations by which the oxide of tin, though less oxygenated than in the former, was yet too much so to produce its best effects.

In stating as my opinion, that tin is most efficacious in raising and giving brightness to colours, when *but little* oxidated, I purposely avoided the word *least*, because my experiments do not warrant me to say that colours are not as much exalted, and enlivened, by a muriate of tin, to which a little nitric, or a little sulphuric acid has been added, (after the solution was made) as by the muriate alone, when recently made; provided that only one of these acids be added; for both together would, as has already been observed, render the tin incapable of producing, with cochineal, any thing more elevated than a salmon or orange colour. But in attributing such effects

to variations in the degrees of oxidation, at which tin is employed, I desire not to be understood as believing, that these *alone operate*, in producing differences in the shades of cochineal colours, or that the several acids employed do not exercise a very considerable influence, in this respect, by their peculiar properties, independently of their effects in oxygenating the metal itself.

In concluding these observations concerning the muriate of tin, I beg leave to repeat, what has been already mentioned, that though it certainly acts more strongly than any other solution of that metal, in weakening the fibres of wool, especially when the acid is saturated by the metal, it may, when the latter is dissolved more sparingly, be employed with perfect safety, (and a considerable saving of expence) and more expecially in conjunction with the usual proportion of cream of tartar; and even with a considerable proportion of sulphuric acid, which indisputably, though perhaps unaccountably, moderates this hurtful action of the muriate of tin,* as indeed *every other acid* seems to do.

*A manufacturer who supplies the Country dyers with not only the muriate, but the murio-sulphate of tin (recommended at p. 483,) assures me, that to produce the *latter* he first prepares the muriate of tin, which he sells of two sorts; in one of which the dissolved metal amounts to a fourth, and in the other to a fifth part of the solution; and by gradually adding to either of these

I have mentioned with approbation, between pages 385 and 392, the results of several experiments made, by MM. Thenard and Roard, to ascertain the effects produced on wool, by boiling it with the usual proportions of alum and tartar, and also with the usual proportions of the latter, and of the nitro-muriate of tin, as employed for the dying of *scarlet*; and it seems proper that I should here notice some other prts of their "*memoire*," which relate more immediately to the production of this colour.

"Scarlet, they say, is obtained by treating wool with determined proportions of cochineal, acidulated tartrite of pot-ash, and a *highly oxydized solution of tin*." "The operation is divided

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two-thirds of its weight of concentrated oil of vitriol, he produces a murio-sulphate of tin, in which, however, the acids are not more than half saturated; but, notwithstanding the great strength of these acids, the solution has not been even suspected of producing any injury to cloth dyed with it; and the preparer of it asserts, that it produces the best effects after being kept several years. No length of time which has elapsed since it was first made and recommended by me, seems capable of diminishing its *colourless transparency*, which equals that of the clearest spring-water; a circumstance which seems not a little extraordinary, when we consider that sulphuric acid *alone* is speedily decomposed by tin; sulphur being *distinctly* produced, and the tin itself converted to a brownish calx, which subsides in a *mass* to the bottom of the vessel, in which the decomposition has been effected.

into two parts; the first taking up an hour and a half, and the second half an hour:" "This division (they add) is necessary to produce a good colour, which would be weaker and more yellow if all the substances were mixed in the first operation and applied to the wool for two hours," by reason of the acidity of the bath, or dying liquor. "We obtain," say they, a contrary effect when the mordants *only* are employed in the first operation, and the cochineal is reserved for the second." They, however, contradict this *last* position, in another part of the same memoir, by asserting that wool, combined with the mordants in question, and dyed afterwards separately with *cochineal only, will never become scarlet*; because this colour, as they allege, can only be produced by a cochineal bath, which is very acid "tres acide," "et qui en faisant *passer au jaune*, le ton de la cochenille, donne alors tant d'eclat à cette couleur."* But the effect of tartar, which principally causes this approach to yellow, in the cochineal colour, may, as I have found by scores of experiments, be very well produced, together with that of the solution of tin, by the *first* boiling; and a very fine scarlet be afterwards dyed by the *second* with cochineal alone, taking care only, when no tartar or tin is intended to be employed

* See Ann. de Chimie, tom. lxxiv. p. 290.

in the last operation with the cochineal, that a full proportion of them be employed in the first, and that their effects be not removed or diminished by *wrincing the cloth*, between the first and second boilings. In regard to the inconvenience of dying scarlet by a *single* operation or *boiling*, I will only observe, in addition to what I have stated on that subject at p. 454, that where *only a bare sufficiency* of cochineal is employed, with a *full* proportion of the mordants, and especially of tartar, the colour, though very lively, will appear rather deficient in quantity, or body, because the cloth will not completely *exhaust* the dying liquor of its colour, when the acids are in excess. This, however, will not ultimately be attended with any waste of colour, because dyers, by a *succession* of undyed pieces, know how to take up, and fully avail themselves of every thing left by a former operation.

In regard to the high degree of oxidation of tin, which these gentlemen consider as necessary for producing a scarlet, I must conclude, that they have been misled by the opinion of Pelletier on this subject, or that they have supposed the solutions employed by them to be much more oxygenated than they really were. Certainly I have produced, as I believe, more than one hundred times, scarlets as beautiful as can be any where found, by the *recent*, and lit-

tle, perhaps least, oxidated muriate of tin, with only the usual proportions of tartar and cochineal; and I have very often found myself unable to produce any thing better than an orange or a salmon colour, by solutions of tin, which certainly were *highly oxygenated.* Indeed, the dyers notoriously and universally consider their spirit, or nitro-muriatic solution of tin, as being unfit for their purpose, when it looses its transparency; an effect which indicates, and results from a greater degree of oxygenation in the metal.*

In another part of their memoir, these gentlemen are pleased to say, that though the process for dying scarlet has long been known, no person has made any theoretical researches, concerning the phenomena which occur, when the solution of tin, cream of tartar, and cochineal, are made to act upon, or with each other,

* I have said, at p. 508, that the straw or amber colour of the solution of tin, commonly employed by dyers, appeared to result from the neutral salts which it holds in solution. I have, however, since discovered that I was then misled by an experiment which ought to have been differently explained, and that *this* colour may be instantly either produced, or increased, by adding a very little muriate of tin to the nitro-muriate of that metal; the former, by being thus added, producing a decomposition of the nitric acid in the latter, and a disengagement of *reddish nitrous gas,* which occasions the colour, and affords an additional proof of my assertion, at p. 507, that the nitric acid is never completely decomposed, in the dyers' spirit, or nitro-muriate of tin.

'dans le traitement de la dissolution d'étain avec la crême de tartre et la cochenille;" adding, that I, who (as they observe) have occupied myself with great success in dying, have indeed endeavoured to explain what occurs in the formation of the scarlet colour; but that as my opinion does *not seem to them to have been founded upon any experiment*, they are intitled, notwithstanding that opinion, to consider the question as being no more decided, than it was before the publication of my work.* As these gentlemen distinctly assert, in this their memoire, that the production of a *scarlet* colour, (instead of a rose or crimson) by the common process, is due to the action of the acid of tartar, and as this is precisely what I had distinctly asserted and maintained *sixteen years before*, I must understand them not as intending to controvert my opinion, but to represent it as one which, though correct, had been formed or *hazarded*, without any experiment or evidence; and that, therefore, what I had done, was of little or no

* "Le Docteur Bancroft, qui s'est occupé avec beaucoup de succés, de la teinture, à bien cherché indiquer ce qui se passe dans la formation de cette couleur, mais comme son opinion ne nous parcit appuyée sur aucune expérience, nous n'en devions pas moins regarder cette question comme aussi peu avancée qu'elle l'étoit avant la publication de son travail." Ann. de Chimie, tom. 75. p. 288.

value, and that they were alone entitled to the credit of having ascertained and established an important fact.

Not finding in myself any desire to conceal, overlook, or undervalue the labours of others, to render my own more important, I am unwilling to suspect that desire in these gentlemen; but I can only avoid doing so, by supposing, that when they ventured to represent me as having made no experiment on this subject, they were not only ignorant of, but culpably negligent in ascertaining the truth, as they might have done by recurring to the statements between pages 284 and 288 of the volume published in 1794, (now reprinted between pages 475 and 479 of this volume) which abundantly manifest that the opinion in question, was not only supported, but had been forced upon me, by a great number of decisive experiments.

Broad-cloths, as commonly manufactured, vary in width from 60, to 63 inches; and they vary also considerably in substance or weight. Of three samples of scarlet broad-cloth which I weighed, the heaviest, said to be Mr. Nash's, was equal to one pound eight and one half ounces per yard, and the lightest to one pound two ounces and one-tenth. Cloths when dyed of the greater part of the colours in use, shrink and acquire weight; but when dyed scarlet, they, by reason of the action of the acids employed,

become of *less weight*, and each piece is made a yard or two longer; the effect of *fulling* being in some degree undone; and when so lengthened, they are said to be *leached.*

Having thus communicated the results of my observations on the uses of tin, in various combinations, as a mordant upon wool with the cochineal colouring matter, it remains for me to state, as shortly as possible, the effects of other bases with the same colouring matter also upon wool or woollen cloth.

Cochineal with nitro-muriate of platina, dyed a red; which, by the addition of carbonate of lime, became a chesnut colour.

With nitro-muriate of gold, it dyed a reddish brown.

With nitrate of silver, a dull red; and with muriate of silver, a lively reddish orange.

With the acetite of lead, a purple, inclining to the violet; and with nitrate of lead, a delicate lively colour, between the red and cinnamon, but inclining most to the former. A little murio-sulphate of tin, added to the liquor in which this last was dyed, soon changed it to a good crimson.

With either the sulphate, nitrate, muriate, or acetate of iron, cochineal produces a dark violet, and even a full black colour, when employed in sufficient quantity.

All the preparations of copper appear to

sadden and debase the colouring matter of cochineal; and all those of mercury, which I have tried, do this in much greater degrees; most of them, whilst they debase the colour, seem to annihilate or render *latent* a considerable part of it.

With nitrate of zinc, cochineal dyed a lively strong lilac colour approaching nearly to purple; and,

With muriate of zinc, a colour like the preceding, but inclining a little more to the purple. Probably the iron usually contained in zinc may have contributed in these instances to incline the cochineal crimson so much to the blue or violet shades, since an oxide of zinc, in some very pure lapis caliminaris, being dissolved by muriatic acid, dyed (with cochineal) a scarlet, but little inferior to that commonly produced with the nitro-muriate of tin and tartar, except in being a little more yellow; and upon adding a little murio-tartrite of tin to the dying liquor, it soon produced a good scarlet. The pure oxide of zinc, therefore, seems to approach nearest to that of tin, in exalting the colouring matter of cochineal; though I believe the colours resulting from it are less durable than those with the basis of tin.

With different solutions of bismuth, cochineal produced various shades of lilac; some of them very lively and delicate; but all prepa-

tions of this semi-metal, instead of displaying and exalting the cochineal colour, tended to render a part of it latent. The oxide of bismuth, dissolved in strong vinegar, did this less than most of the other preparations; it dyed with cochineal a pretty good purple, and the murio-sulphate of bismuth, a salmon colour.

With nitrate of cobalt, cochineal dyed a good purple, and a violet with the sulphate of that metal.

With nitrate of nickle, a dark lilac, inclining to the violet.

With yellow oxide of tungsten, cochineal dyed a red much like that commonly obtained from madder.

With sulphate of manganese, an orange; and

With the nitrate of Manganese, a colour resembling the madder red.

With crude antimony, which had been subjected to the action of nitric acid, cochineal dyed a scarlet very much like that dyed with lapis caliminaris dissolved by muriatic acid, and but little inferior to the best scarlets given with the tin basis; and

With Macquer's arsenical neutral salt, or the acidulous arseniate of pot-ash, cochineal dyed a lively good purple; and with common white arsenic a full dark lilac colour.

Such were the effects of different metallic

bases, in dying with cochineal on woollen cloth. Of the simple earths I have only tried alumine and silex as bases with cochineal. Those of Zircon, Glucine, (or Glycine) and Yttria (or according to Dr. Young, Ittria) being too *rare* and *costly* for this use.

The effects of sulphate of alumine, or common alum, with cochineal, and especially in dying crimson, are well known. Alumina, or earth of alum, (obtained by descomposing and precipitating it by pot-ash from water, saturated with alum,) when thoroughly washed, dried, and finely powdered, did not seem capable, in repeated trials, of *alone* fixing or serving as a basis of the cochineal colour on wool. In this respect it differed from the powdered calx of tin.

But the powdered alumine, being boiled up with cream of tartar, was so far dissolved by its acid, that with cochineal it dyed a good crimson, though not much better than that which may be produced with the sulphate of alumine.

The same powdered earth of alum, dissolved by lemon juice, dyed with cochineal a very good rich full crimson.

The same powdered earth of alum dissolved by nitric acid, (and forming nitrate of alumine,) produced a good red, inclining to the crimson.

The same dissolved in muriatic acid, (mu-

riate of alumine) dyed a crimson, differing but little from that produced with common alum.

The silicated alkali of Dr. Black, or powdered flints, dissolved by a violent heat in a crucible, with pure caustic alkali or pot-ash, was tried as a basis for the cochineal colour. At first, the fibres of the cloth did not seem to have sufficient attraction for the siliceous basis and the colouring matter, to attach and fix them properly; but on adding a little sulphuric acid, so as to decompose and neutralize a part of the alkali, which had dissolved and was combined with the siliceous earth, the colour took freely, and rose to a *full, rich, pleasing purple,* in which the red or crimson predominated considerably; and this colour afterwards proved sufficiently durable.

In regard to *alkaline* earths, (so called) I found that lime water with cochineal dyed a purple, which took but slowly, and required long boiling.

That sulphate of lime, or lime dissolved by sulphuric acid, dyed a full dark red.

That nitrate of lime, or lime dissolved by nitric acid, dyed a lively red, approaching to scarlet.

And that muriate of lime with cochineal dyed a purple.

Cloth boiled in water with *nitrate of lime,* and then dyed in clean water with cochineal and tin,

dissolved by aqua-fortis and tarter mixed, received a good scarlet.

Cloth boiled with carbonate of lime and alum, and then dyed in clean water with cochineal, took a good crimson, inclining to the bluish shade.

Sulphate of barytes, or ponderous spar, not being soluble in water, was not tried.

But muriate of barytes, employed as a basis for the cochineal colour, dyed a good lively purple; and

Nitrate of barytes dyed a colour nearly similar, but inclining a little more to the crimson.

Magnesia alone did not combine sufficiently with the fibres of cloth, and with the colouring matter of cochineal, to serve as a basis for dyeing.

But magnesia dissolved by sulphuric acid, (forming Epsom salt,) dyed a lively purple with cochineal, though it took but slowly, and required long boiling. The acetate of magnesia dyed a lilac colour.

Strontites, or strontia earth, dissolved by muriatic acid, and employed as a mordant with cochineal, produced on woollen cloth an orange colour.

It appears, therefore, that besides the metallic oxides and solutions, the *simple* earths, so far as they have been tried, and *all* the *alkaline*, are capable of serving as bases of the cochineal

colouring matter; though not with equal advantage, and we shall hereafter find, that they are capable of doing the same to other adjective colours; a fact never before ascertained, though of great importance, as well in respect of the practical improvements which it may produce, as of the general principles and conclusions to which it may lead us on this subject.*

I have repeated nearly all the foregoing experiments with silk, instead of wool, and generally with effects less advantageous. Cochineal, indeed, with the aluminous basis, dyes the crimson colour as well and as durably on silk as on wool, and the modes of producing a very lasting crimson by these means are well known. But the oxides or solutions of tin tend to diminish the shining glossy appearance of silk, and, therefore, when applied to it do not reflect the cochineal colour with the same degree of fulness and lustre as upon wool; and it has, therefore, been found impossible to dye a good lively scarlet on silk by the means which communicate that colour to wool.

* I have found that cochineal has so much affinity for wool, that if the latter be boiled with a portion of sulphuric acid sufficiently diluted, and afterwards dyed with cochineal, it will, without any other basis, take a *red* colour, capable of bearing exposure to the sun and air for some weeks, though fewer than if dyed upon a suitable basis. But cotton will take no colour in this way.

The late Mons. Macquer, indeed, about the year 1768, pretended to have discovered the means of dyeing a scarlet upon silk by a process which he published in the Memoirs of the Royal Academy of Sciences for that year. According to that process, he began by dying the silk first of a yellowish orange colour, with annotta applied in the usual way; then he soaked it for half an hour in a diluted solution of tin, made by a mixture of two parts of the nitric with one of the muriatic acid; after which the silk was taken out, moderately pressed, and rinced in clean water, though he afterwards found it better to omit the rincing. To dye the silk, when thus impregnated with nitro-muriate of tin, he prepared a bath, by boiling from two to four ounces of cochineal and a quarter of an ounce of cream of tartar, for each pound of silk, some minutes in water; after which he added cold water, until the heat of the liquor was reduced to what the hand could bear, and then put in the silk, and dyed it as usual, gradually raising the heat of the dyeing liquor, so as at last to make it boil for a single minute. I have several times repeated this process, but always found the colour produced by it very inferior to the scarlets usually dyed on woollen cloth; and M. Berthollet informs us, that this was also the case at the trials which Mr. Macquer himself made of his process at the dye-house of the Gobelines; and in truth there was nothing of any

importance in Mr. Macquer's supposed discovery. It seems, indeed, to have been chiefly borrowed from a process published by Scheffer, in 1751, excepting so far as relates to the colour first given with annotta, and excepting a difference in the proportion of muriatic acid for dissolving the tin; a difference, however, which did not render the solution in any respect more efficacious.

If the murio-sulphuric solution of tin, herein before described, be diluted with about five times its weight of water, and silk be soaked in it for the space of two hours, then taken out, moderately squeezed or pressed, afterwards partly dried, and then dyed, as usual, in a bath prepared with cochineal and quercitron bark, in the proportion of four parts of the former to three of the latter, it will receive a colour approaching very nearly to a scarlet; and this may be made to receive more body by a farther slight immersion into the diluted murio-sulphate of tin, and a second dyeing in the bath with cochineal and quercitron bark; and if afterwards a little of the red colouring matter of safflower be superadded by the usual mode of applying it, a good scarlet may be produced. By omitting the quercitron bark, and dyeing the silk (prepared as before mentioned) with cochineal only, a very lively rose colour will be produced; and this may be yellowed so as nearly to ap-

proach the scarlet, by adding a large proportion of tartar to the cochineal in the dyeing vessel.

With lime water as a mordant, cochineal gave to silk a very agreeable purple; with muriate of barytes, a lively delicate lilac colour; with murio-sulphate of bismuth, a salmon colour; and with nitrate of cobalt, a very lively and beautiful purple; with nearly all the other metallic and earthy bases cochineal produced similar, but paler, colours on silk than on wool.

The scarlet dye is still less applicable to *cotton* than to silk, there being, unfortunately, but a slight affinity between the former and the oxide of tin, even when united with the colouring matter of cochineal. This was demonstrated by the late M. Dufay, who caused a piece of cloth to be manufactured from a mixture of wool and of cotton, which having undergone the usual process for dyeing scarlet, became, as he describes it, " marbrée de couleur de feu et de blanc," (marbled with white and fire colours,) the cotton remaining perfectly white, though the wool was dyed scarlet: and he found a like want of attraction between cotton and the colouring matters of kermes and stick lac. He moreover found that a skein of white woollen yarn, and another of cotton, being at the same time, and in an equal degree, submitted to the action of the same preparation,

and dyeing liquors, which are commonly employed for scarlet, the woollen yarn received a beautiful scarlet, or, as he terms it, "*fire colour*," whilst the cotton remained as white as at first.* †Similar effects have frequently occurred to me, and I have clearly perceived them to arise, not because the cotton is not capable of imbibing the scarlet dye; but because, having a weaker attraction for it than that which wool exerts on the particles of that dye, the latter *draws, and exclusively appropriates to itself*, all the colour contained in the dyeing liquor; though when cotton is subjected to the same process by itself, freed from the interference of a superior attraction from wool, it takes a scarlet colour, as I know by repeated trials, more slowly, indeed, and paler, than that which is usually imbibed by woollen cloth. It is, perhaps, owing to this weaker attraction between the fibres of cotton,

* See Mem. de l'Acad. Ro. des Sciences, &c. 1737.

† In the dyeing of scarlet, it is every day seen, that pieces of woollen cloth or stuff, having at each edge a narrow longitudinal stripe, formed by an intermixture of cotton yarn, after being impregnated in the usual way with the mordant or oxide of tin, will attract and imbibe the colouring particles of cochineal, so as to exhaust the dyeing liquor, and sometimes leave it perfectly colourless, and become scarlet in every part, excepting the stripes formed of cotton-yarn, which always come out of the dyeing liquor without the smallest tinge or change of colour, though both the mordant and the particles of cochineal are applied to the latter equally with the other parts of the cloth.

and the scarlet dye, that the latter is so much less permanent on cotton than on wool; and it is also from this want of sufficient attraction, that the cochineal colour is found to take most beneficially on cotton, when the basis has been *first applied separately.*

Scheffer, in 1751, recommended the dyeing of scarlet on cotton in this way, by first soaking it in a diluted nitro-muriate of tin, and afterwards dyeing it with cochineal; but the colour being fugitive, little or no use was ever made of the process; though the late Dr. Berkenhout probably availed himself of it some years afterwards, when he pretended to have discovered the means of dyeing "scarlet, crimson, and other colours, upon cotton and linen;" and though his process was not materially different from that of Scheffer, nor in any respect preferable to it, he found means to obtain 5000l. sterling from the British government, as a reward for making it public.* But as no use ever has

* Dr. Berkenhout's process having, I believe, never been published, I shall subjoin the account of it, which was "communicated by order of the Lords of the Treasury to the Company of Dyers in the City of London, the 26th of August, 1779;" *viz.*

"Cotton or linen, either in yarn or the piece, should be perfectly wet with hot water, and then wrung out, as is the common practice.

"This being done, it must be perfectly soaked in a solution of tin, diluted with an equal quantity of clear soft water.

been, or is likely to be made of this supposed discovery, I must hope, and, indeed, I think it

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"The cotton or linen being so far prepared, must be wrung out, but not forcibly; then it is to be nearly dried, laying horizontally upon a hurdle, with a double linen sheet between and covered with the same.

"The solution of tin being for scarlet, must be made of nitrous acid, and not of aqua-fortis; but for crimson, aqua-fortis must be used; and the bloom is to be given, after it comes out of the dye, by a small quantity of sal-ammoniac and pearl ashes, dissolved perfectly in warm water; but this water must not be more than milk-warm.

"The colouring vat, for the scarlet or crimson, is simply cochineal in water, no hotter than the hand will bear; and as vegetable matter receives only the small particles of the colour from the nature of its pores, two ounces to a pound of the materials dyed may be necessary; but cotton or linen, fresh prepared, will draw from the same vat, heated as before, all the inferior shades from scarlet and crimson; and if any colour still remains in the vat, it may be taken out entirely by wool prepared in the usual manner.

"The same preparation of tin serves for the green and yellows, with the same materials only that are employed by dyers, except the best yellow, which is produced from turmeric.*

"It is necessary to observe, that after the preparation has been made use of for scarlet or crimson, the residue continues sufficiently strong for greens or yellows, even after it has been kept a considerable time.

"N. B. To make the best solution of tin with nitrous acid, it is necessary to have the strong smoking spirit, to which

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* Nothing can be more erroneous than this and several of Dr. Berkenhout's other observations.

probable, that the Doctor had some better claim to a national remuneration, though, from particular considerations, it was not brought into public view.

Besides the fugitive nature of the scarlet dyed by Dr. Berkenhout's process, which, indeed, is calculated to produce only a crimson, and not a scarlet, unless some yellow colour be superadded by other means (which he does not mention,) it is liable to injure the texture of the cotton or linen dyed with it, because the nitric calx of tin, applied as the basis, constantly absorbs oxygene from the atmosphere, and becomes corrosive, whereas, in the present case, this effect cannot be counteracted by occasional washings with soap.

Mr. Henry says, that "if a scarlet could be dyed without the use of nitrous acid, the tin basis might be employed for this purpose on cotton; but *that acid being requisite for the production of this beautiful colour*, and being

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an equal quantity of the purest river water must be added, and the proportions of the following ingredients, are to the weight of spirit, one-sixteenth of sal-ammoniac and one-thirty second of refined nitre dissolved by little at a time; in this aqua-regia dissolve one eighth of granulated tin, also by small quantities, to prevent too great an ebullition, which would weaken the solution cosiderably. The ingredients and proportions are the same, when a solution is to be made with aqua-fortis; but that spirit, in general, will not bear any water when a perfect solution is intended."

highly corrosive to colours, this basis is prevented from being applied to that substance."—Here this ingenious chemist appears to have fallen into the universal error of believing, that nothing but a solution of tin by nitric, or nitrous acid, can dye a scarlet colour with cochineal.

If, notwithstanding the want of sufficient permanency in the scarlet colour dyed with cochineal upon cotton, it should be deemed proper to apply it to that substance, the best way of doing this which I have yet found, is, to soak the cotton (previously moistened) for about half an hour in a diluted murio-sulphuric solution of tin, as proposed for silk; then wring or press out the superfluous part of the solution of tin, and plunge the cotton into water, in which as much, or nearly as much, clean potash or soda has been dissolved as will neutralize the acid still adhering to the cotton, so as thereby to decompose the oxide of tin, and cause it to be more copiously deposed or fixed in or upon the fibres of the cotton, which, being afterwards rinced in clean water, may be dyed with cochineal and quercitron bark, in the proportions of about four pounds of the former to two and a half or three pounds of the latter. A full bright colour may be given to cotton in this way, which will bear a few slight washings with soap, and a considerable degree of exposure to air. Indeed,

the yellow part of the colour obtained from quercitron bark will even bear long boiling with soap, as well as the application of strong acids, without injury.

Cotton impregnated or printed with the aluminous mordant, as commonly applied by calico-printers for madder reds, will, if dyed with cochineal, receive a very beautiful crimson colour, capable of bearing several washings, and of resisting the weather for some time, though not long enough to deserve the appellation of a fast colour. I think, however, that it is advantageous for calico-printers, in dying madder reds upon the finer cottons or muslins, to add also a little cochineal, the crimson colour of which is admirably calculated to overcome the yellowish hue that degrades the madder reds, and arises from a portion of that particular colouring matter which produces the *fauve*, or fawn colour, herein before mentioned. By this addition, the madder reds are rendered much more beautiful, so long as any part of the cochineal crimson remains, and afterwards they are no worse than if it had never been applied.

Cotton printed with iron liquor takes a very full black when dyed with cochineal; but I found this less durable than the same colour dyed from much cheaper matters. A great variety of other colours may be dyed upon cotton impregnated

with different metallic or earthy bases ; but as better colours may be more cheaply given by other means, I shall offer no farther explanations respecting them.

A strong decoction of cochineal, thickened with gum, and mixed with a suitable proportion of nitrate of alumine, being penciled upon cotton as a pro-substantive colour, afforded a very full beautiful colour between the scarlet and crimson, which stood some washings, and a considerable degree of exposure to weather. Several of the different solutions of tin being employed, instead of the nitrate of alumine, as well as conjointly with it, produced very beautiful rose colours, approaching more or less to the scarlet ; and by adding a small proportion of the quercitron bark, they were made scarlet. They could not, indeed, be considered as fast colours, but had the advantage of being very beautiful, and less fugitive than many of those which are too frequently employed by calico printers, under the denomination of chemical colours.

Since the preparation or manufacture of Morocco leather has been established in this country, *cochineal* is employed to communicate the beautiful colour of *that*, which is called *red* Morocco ; though in Persia, Armenia, Barbary, and the Greek Islands, a similiar colour was originally produced by the use of either *kermes* or *lac*. As a basis for the colouring matter of

cochineal, goat-skins deprived of their hair by lime water, and properly cleansed, are impregnated, on that which was the *hairy side*, with a saturated solution of alum, applied repeatedly and equally by a spunge, and after an interval of three or four days, a decoction of cochineal, which has been strained, is applied also by a spunge, to the same side or surface, a little, but not much, more than blood-warm, least it should crisp the leather. This application is repeated from time to time, until a colour sufficiently full and equal has been produced. Afterwards the skins are soaked in bran liquor, and then tanned by a decoction of either galls or sumach, or of both mixed together.

I have found that by substituting a diluted murio-sulphate of tin, for the solution of alum, or by employing a mixture of both upon goatskins in a suitable state of preparation, the colour subsequently produced was considerably improved, at least in vivacity.

Having nothing more of importance to communicate respecting cochineal, I shall here finish this chapter, and in doing so, make an

END OF VOLUME THE FIRST.

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EXPERIMENTAL RESEARCHES

CONCERNING THE PHILOSOPHY OF

PERMANENT COLOURS.

PART II, continued.

CHAPTER V.

Of the Coccus Ficus, or Coccus Lacca, *and its Nidus, or Comb, commonly called* Lac, Lacca, *or Lácshá.**

> " La chimie des arts ne se borne point à porter son flambeau
> " sur ce qui est connu, ou à perfectionner ce qui se pratique;
> " elle crée, chaque jour de nouveaux arts."
>
> CHAPTAL. Chimie appliquée aux arts. Discours préliminaire.

THIS substance was probably unknown in Europe until after the Portuguese had visited India by sailing round the Cape of Good Hope, and very discordant opinions were entertained of it, for a considerable time after its first importation. Cardanus (de subtilitate rerum, lib. viii.) represented lac as a natural gum, exuding

* Sir William Jones says, " the Hindûs have six names for " Lac; but they generally call it Lácshá, from the multitude " of small insects, who, as they believe, discharge it from their " stomachs, and at length destroy the tree on which they form " their colonies." Dissertations, &c. relating to the History and Antiquities, &c. of Asia, vol. ii.

from a sort of cherry-tree in India.—But this was contradicted by Amatus Lusitanus, in the first book of his annotations upon Dioscorides, where he asserts, that it is the excrement of a species of winged ants in the kingdom of Pegu; which opinion was also delivered by Christopher Acosta, in his treatise de Hist. plant. aromatumque Indiarum Orientalium.

Caneparius, after noticing these opinions, (and others proposed by Garzia ab Horto, Clusius, &c.) endeavoured to convince his readers, that lac was produced by the sap, or juice, of certain trees, wounded by a species of ants, which, by exposure to the air, acquired the hardness of a gum, and retained some of the ants, which, as he supposed, had been caught and entangled therein by its viscidity. He adds, that being boiled, it was employed to give cloths a red colour by dying, and that the colouring matter left in the dying vessel, being afterwards formed into a mass by evaporation, was called an artificial *lac*, and employed by painters.* He adds, that similar *pigments*, being afterwards prepared from the colouring matters of kermes, Polish cochineal, (or coccus Polonicus) Brazil

* "Iccirco coquitur pro tingendis pannis colore rubeo; mox ex ipsius reliquiis post tincturam panni conficitur massa quæ dicitur Lacca artificialis qua utuntur pictores." De Atramentis, &c. p. 214.

wood, &c. remaining in the liquors in which cloth and silk had been dyed with these matters, such pigments were called by the Italians lacca, adding to this name that of the substance whence the colour was obtained, as "lacca di verzino (Brazil wood) lacca di *grana*, lacca di cremise," &c. and this explanation enables us to ascertain the origin of the English word *lake*.

A much more correct account of lac, and of the insects producing it, was given by Mr. James Kerr, of Patna, in a communication to the Royal Society, which was published in the Philosophical Transactions for 1781. By this account it appears, that when the *lac* insect is first brought forth in November and December, "the head and trunk form one uniform oval "compressed *red* body, of the shape and magnitude of a very small louse, consisting of "twelve transverse rings; the back is carinate, "the belly flat, the antennæ half the length of "the body, fili-form, truncated, and diverging, "sending off two, sometimes three, delicate "diverging hairs longer than the antennæ." The tail is "a little white point, sending off "two horizontal hairs, as long as the body." The insect had three pair of limbs half of its own length; but no wings were seen by Mr. Kerr. As soon as they are brought forth, the insects begin to "traverse the branches of the

"trees upon which they were produced for "some time, and then fix themselves upon the "succulent extremities of the young branches. "By the middle of January they are all fixed "in their proper situations, and appear as plump "as before, but shew no other marks of life. "The limbs, antennæ, and setæ of the tail, are "no longer to be seen. Around their edges "they are environed with a spissated subpel-"lucid liquid, which seems to glue them to the "branch. It is the gradual accumulation of "this liquid which forms a complete cell for "each insect, and is what is called gum lacca. "About the middle of March the cells are "completely formed, and the insect is in ap-"pearance an oval smooth red bag, without "life, about the size of a small cuchanical "insect, emarginated at the obtuse end, full of "a beautiful *red liquid.* In October and No-"vember we find about twenty or thirty oval "eggs, or rather young grubs, within the red "fluid of the mother. When this fluid is all "expended, the young insects pierce a hole "through the back of their mother, and walk "off one by one, leaving their exuviæ behind."

According to Mr. Kerr, the lacca insects in the country where he wrote, were found in four species of shrubs: First, Ficus Religiosa, Lin. Second, Ficus Indica, Lin. Third, Plaso Hortus Malabaraci; and, Fourth, Rhamnus Jujuba,

Lin.—They fix themselves in such multitudes on these trees, and more especially of the three first, that "the extreme branches appear as if they were covered by a red dust; "and their sap is so much exhausted, that "they wither and produce no fruit." Birds perching on these branches carry off great numbers of the lacca insects, adhering to their feet, and transplant, by depositing them, on other trees where they rest.

"The gum lacca of this country (says Mr. "Kerr) is principally found upon the uncultivated mountains on both sides of the Ganges, "where bountiful nature has produced it in "such abundance, that were the consumption "ten times greater than it is, the markets "might be supplied by this minute insect. "The only trouble in procuring the lac is in "breaking down the branches, and carrying "them to market. The present price in Dacca "is about 12s. the 100lb. weight, although it is "brought from the distant country of Assam. "The best lac is of a *deep red* colour. If it be "pale, and pierced at the top, the value diminishes, because the insects have left their "cells, and consequently they can be of no use "as a dye or colour:" though the lac itself may be better for varnishes.

The lacca is capable of being applied to several uses. That of dying, however, is alone

the object of our present inquiry; and for this it is supposed to have been known and employed by the ancients; but this cannot be ascertained, because they have left no description of it sufficiently accurate. (See Salmas. Exercit. p. 810.)

By Mr. Kerr's account, the native Indian inhabitants, after extracting the colouring matter of the lac by hot water, mix alum and tamarind water with the decoction, and dye silk and cotton therein.

A further account of the lac insect was, a few years afterwards, communicated to the Royal Society, by Mr. Robert Saunders, and published in the Philosophical Transactions for 1789, of which the following are extracts, *viz.*

" Lac is known in Europe by the different appellations of *stick* lac, *seed* lac, and *shell* lac. The first is the lac in pretty considerable lumps, with much of the woody parts of the branches on which it is formed adhering to it.* *Seed* lac is only the stick lac broke into small pieces,

* *Stick* lac is properly the lac in its *natural state,* adhering to, and often completely surrounding, for five or six inches, the *twigs* on which it is produced by the insects contained in its cells. When the twigs or sticks are large, and only partially covered, the lac is frequently separated from the sticks, as, indeed, it ought always to be when shipped for Europe, to avoid paying freight uselessly for the latter. Sometimes pieces of lac, with or without the twigs, after having been exposed to great heat from the Sun, cohere and form lumps.

garbled and appearing in a granulated form.* *Shell* lac is the purified lac by a very simple process, to be mentioned afterwards.†

" The tree on which this fly most commonly generates is known in Bengal by the name of the biher tree, and is a species of the rham-

* This account of seed lac is very incorrect. When *lac* has been separated from the twigs to which it naturally adheres, and coarsely pounded, the silk and cotton dyers extract the colour, as far as it can conveniently be done, by water; after which the yellowish *hard resinous* powder, in appearance somewhat resembling mustard seed, is called *seed* lac. I have compared samples of seed lac as imported and deposited in the warehouses of the India Company, with powdered stick lac, treated in the way just described, for my own experiments, and have found *both to be exactly similar* in appearance and in the fact of their containing but a small, and nearly an equal *remnant* of colouring matter.

† *Shell* lac is produced from *seed* lac, by putting the latter into long cylindrical bags of cotton cloth, and melting it, by holding the bags over a charcoal fire, and when the lac melts, straining, or forcing it through the pores of the cloth, by twisting the bags; which is done by two men, one holding each end of a bag. The lac so strained, is made to fall upon the smooth junk of a plantane tree, (*Musa Paradisiaca*) and is there spread into thin plates, or lamellæ.—The resin being the most liquifiable part of the lac, it thus passes, almost exclusively, through the strainer, and in a considerable degree of purity.

Shell lac is principally employed in Europe to compose varnishes and sealing-wax. The latter use of it, was noticed by Garzia ab Horto, in 1563. (See Aromatum et simplicium aliquot Historia, &c.)

nus.* The fly is nourished by the tree, and there deposits its eggs, which nature has provided it with the means of defending from external injury by a collection of this lac, evidently serving the two-fold purpose of a nidus and covering to the ovum and insect in its first stage, and food for the maggot in its more advanced state. The lac is formed into complete cells, finished with as much regularity and art as a honey-comb, but differently arranged. The flies are invited to deposit their eggs on the branches of the tree, by besmearing them with some of the fresh lac, steeped in water, which attracts the fly, and gives a better and larger crop.

"The lac is collected twice a year, in the months of February and August.

"I have examined the egg of the fly with a very good microscope; it is of a very *pure red*, perfectly transparent, except in the centre, where there were evident marks of the embryo forming, and opaque ramifications passing off from the body of it. The egg is perfectly oval, and about the size of an ant's egg. The maggot is about one eighth of an inch long, formed of many rings, (ten or twelve) with a small red

* This is a mistake; the biher, or bihar tree, is the croton lacciferum, Lin. which seems to be generally preferred by the lac insects. It is described by Loureiro, Cochinchina, i. p. 582.

head; when seen with a microscope, the parts of the head were easily distinguished, with six small specks on the breast, somewhat projecting, which seemed to be the incipient formation of the feet. This maggot is now in my custody, in the form of a nymph, or chrysalis, its annual coat forming a strong covering, from which it should issue forth a fly.

" Nature has provided most insects with the means of secreting a substance which generally answers the two-fold purpose of defending the embryo and supplying nourishment to the insect, from the time of its animation till able to wander abroad in quest of food. The fresh lac contains within its cells a liquid, sweetish to the taste, and of a fine red colour, miscible in water. The natives of Assam use it as a dye, and cotton dipped in this liquid makes afterwards a very good red ink.

" *Assam* furnishes us with the greatest quantity of lac in use; and it may not be generally known, that the tree on which they produce the best and largest quantity of lac, is not uncommon in Bengal, and might be employed in propagating the fly, and cultivating the lac, to great advantage. The small quantity of lac collected in these provinces, affords a precarious and uncertain crop, because not attended to. Some attention at particular seasons, is necessary to invite the fly to the tree; and collect-

ing the whole of the lac with too great an avidity, where the insect is not very generally to be met with, may annihilate the breed."

Of the four species of shrubs upon which, Mr. Kerr says, the lacca insects are found in the countries adjacent to Patna, there is only one, the rhamnus jujuba, upon which Dr. James Anderson could find them near Madras, though he observed them on several species of mimosa, and on some other trees and shrubs.

Dr. Roxburgh, indeed, seems to think, that on the coast of Coromandel they only inhabit shrubs of the mimosa kind, and even but three species of this genus. He says, (see Philos. Trans. 1791,) that "some pieces of fresh looking lac adhering to small branches of the "mimosa cinerea, Lin. were brought to him "on the 20th November, 1789;" and being carefully kept in wide-mouthed crystal bottles, slightly covered, after fourteen days had elapsed "thousands of exceeding minute red animals "were observed crawling about the lac and the "branches it adhered to, and still more were "adhering to the surface of the cells. By the "assistance of glasses, small imperforated ex-"crescences were also observed interspersed "among the holes; two regularly to each "hole, crowned with some very fine white "hairs, which being rubbed off, two white "spots appeared. The animals, when single,

" ran about pretty briskly; but in general, on
" opening the cells, they were so numerous as
" to be crowded over one another.

" The substance of which the cells were
" formed, cannot be better described, (says Dr.
" Roxburgh) with respect to appearance, than
" by saying, that it is like the transparent
" amber that beads are made of. The external
" covering of the cells may be about half a
" line thick, is remarkably strong, and able to
" resist injuries; the partitions are much
" thinner. The cells are in general irregular
" squares, pentagons, and hexagons, about an
" eighth of an inch in diameter, and a quarter
" of an inch deep; they have no communica-
" tion with each other. All those I opened,
" during the time the animals were issuing from
" them, contained in one side, which occupied
" half the cell, a small bag filled with a thick
" red jelly-like liquor, replete with what I take
" to be the eggs. These bags, or utriculi,
" adhere to the bottom of the cells, and have
" each two necks, which pass through perfora-
" tions in the external coat of the shells, form-
" ing the beforementioned excrescences, ending
" in some fine hairs.

" The other half of the cells has a distinct
" opening, and contains a white substance, like
" some filaments of cotton rolled together, and
" a number of the little red insects themselves,

"crawling about ready to make their exit. "Their portion of each cell is about one half, "and I think must have contained near one "hundred of these animals. Other cells less "forward, contained in this half, with one "opening, a thick, red, dark, blood-coloured "liquor, with numbers of exceedingly minute "eggs, many times smaller than those found in "the small bags which occupied the other half "of the cells."

Dr. Roxburgh describes the circumstances and progress of these insects, and particularly the females, through the larva and pupa onwards, to their perfect states, which last they did not reach until near five months. The male insect in the perfect state was about the size of a very small fly, and exceedingly active; with an obtuse head, black eyes, oval brown trunk, six legs for running and jumping, and four membranaceous incumbent wings, of which the anterior pair was twice as long as the posterior, but he had no tail.

The female insect, in her perfect state, was rather smaller than the male, and of a brighter red colour, though less active. Her head and eyes were very small; trunk red, and almost orbicular; abdomen red, oblong, and composed of twelve annular segments; she had six legs for running and jumping, with only two long transparent incumbent wings, and a tail consisting of two white hairs as long as her body.

"The eggs, and dark-coloured glutinous li-
"quor they are found in, (continues Dr. Rox-
"burgh) communicate to water a most beau-
"tiful red colour, *while fresh.* After they have
"been dried the colour they give to water is
"less bright; it would therefore be well worth
"while for those who are situated near places
"where the lac is plentiful, to try to extract
"and preserve the colouring principles by
"such means as would prevent them from being
"injured by keeping. I doubt not but in time
"a method may be discovered to render this co-
"louring matter as valuable as cochineal.

"Mr. Hellot's process (adds Dr. Roxburgh)
"for extracting the colouring matter from dry
"lac, deserves to be tried with the fresh lac,
"in the month of October or beginning of
"November, before the insects have acquired
"life; for I found the deepest and best colour
"was procured from the eggs while mixed with
"their nidus. His process is as follows:
"Let some powdered gum lac be digested two
"hours in a decoction of comfrey root, by which
"a fine crimson colour is given to water, and the
"gum is rendered pale or straw coloured. To
"this tincture, poured off clear, let a solution
"of alum be added; and when the colouring
"matter has subsided, let it be separated from
"the clear liquor and dried. It will weigh

"about one-fifth of the quantity of lac em-
"ployed. This dried fecula is to be dissolved
"or diffused in warm water; and some solution
"of tin is to be added to it, by which it ac-
"quires a vivid scarlet colour. This liquor is
"to be added to a solution of tartar in boiling
"water, and thus the dye is prepared.

"In India (says Dr. Roxburgh) comfrey roots
"are not to be had; but any other mucilagi-
"nous root, gum, or bark, would probably an-
"swer equally well. On some parts of the Co-
"romandel coast, if not over it all, a decoction
"of the seeds of a very common plant, (Cassia
"Tora of Linnæus,) which is extremely muci-
"laginous, is used by the dyers of cotton cloth
"blue, to help to prepare the blue vat. It *sus-*
"*pends* the indigo until a fermentation takes
"place to dissolve it, and also helps to bring
"about that fermentation earlier than it other-
"wise would."

Probably some methods of extracting the colouring matter of fresh lac, similar perhaps in a considerable degree to that proposed by Dr. Roxburgh, have been already (1793) attempted in some parts of India. A gentleman to whom I have had occasion to allude several times, lately received from Bengal, where he had formerly resided, a parcel of a colouring matter, which had very much the appearance of pow-

dered cochineal, of which he gave me a few ounces, calling it East-Indian Cochineal, with a request that I would try its effects in dying scarlet. I happened then to have by me a piece of cloth which I had previously prepared for receiving a scarlet from cochineal, (upon a new principle explained in the preceding chapter,) by impregnating it with a muriatic solution of tin, and a certain portion of yellow colour from the Quercitron bark; and I resolved to see whether this East-Indian colouring matter would yield a crimson, capable, when fixed as a dye in the cloth so impregnated and made yellow, of producing a scarlet, as the natural crimson of cochineal would do by the same means. But on boiling the cloth in question with this East-Indian colouring matter, in water, I found it wholly insoluble by this menstruum. However, upon taking out the cloth, and adding a little vegetable alkali, the water immediately assumed a fine crimson colour, the alkali having, as I afterwards discovered, separated the colouring matter from a portion of alumine which had been employed to precipitate it (in India), and to which it was too intimately united to be dissolved by water *only*. Having thus obtained a solution of the colouring matter in question, I decanted off the clear crimson liquor, added to it a little muriate of tin, principally to neutralize

the alkali, and precipitate any alumine which might have been dissolved by it, and then dyed the piece of cloth before mentioned, which took a good scarlet, better indeed than I had been able to give by the lac brought to this country in its natural form; though, from many circumstances and subsequent trials, I am fully persuaded that the colouring matter which produced this effect was in reality nothing but the colouring matter of lac, extracted either when fresh, or by some particular means when dried, and afterwards precipitated either wholly or in part by alum.

A few years since, some persons in this country formed an establishment for extracting the colouring matter of dried stick lac; but it probably did not succeed according to their expectations, since it does not, I believe, now subsist. An extract, answering tolerably well, may be made from this drug, by merely boiling it in water, straining off the coloured liquor, and evaporating it to a solid consistence. The fine red-coloured liquor contained in the cells of the lac is described by some authors as being sweet to the taste, at the same time that it readily mixes with water. Great use is made of it as a dye by the natives of Assam.

The colours dyed by stick lac approach very nearly to those of cochineal. They are indeed

not quite so lively and beautiful, but this defect is in some degree compensated by their being more durable, especially on cotton, where I have employed it with some success topically, with different bases. It has been sometimes a practice to employ a mixture of the colouring matter of lac, with that of cochineal, in producing scarlets, &c. Both require the same basis, and nearly the same treatment. At present, however, almost all the stick lac brought to Europe is afterwards sent to Portugal, Barbary, &c. and employed in staining goat skins to produce the red Morocco leather.

Subsequently to, and in consequence of the preceding observations, (first published in 1794) Mr. Stephens, surgeon to the *East India* Company's establishment at Keerpoy, undertook to prepare an extract of the colouring matter of the lac insect, of which Mr. Fleming, inspector of drugs to *the board of trade* in Bengal, gave the following account, in his letter to that board, dated July 7th, 1796, *viz.*

"Dr. Bancroft, in a very instructive work which he has lately published on the subject of dyeing, mentions, as a desideratum, a method of extracting the colouring matter of lac, and thinks that if it could be formed into a lake and sent home in that state, it would be a far preferable mode to that of sending the stick lac. Encouraged by so good an authority, I herewith

send for your inspection two bottles of a preparation which I have received from Mr. Stephens at Keerpoy, and which appears to me to be exactly what the Doctor desires. Mr. Stephens informs me that he prepared it from *fresh* lac, by a method discovered by himself, and that if it should be found to answer on trial, he will be able to provide a considerable quantity of it every year. I therefore beg leave to recommend, that the accompanying sample may be sent home by the Dart, with a request to the honourable Court of Directors, that it may be forwarded to Dr. Bancroft, for his opinion respecting its value. I have dyed several pieces of kerseymere cloth with it, and was agreeably surprised to find it, even under my inexpert management, to produce so good a colour. I have no doubt that in the hands of a skilful dyer it will bring out as bright and beautiful a scarlet as the cochineal itself. I send herewith one of the pieces of cloth for your inspection. Should the directors send the lake for trial to Dr. Bancroft, it is needless to inform that gentleman, that, in order to render it soluble in water, it is necessary to add to it a little pearl ash; but in case of their giving it to a practical artist, it may be proper to apprize him of this circumstance, as also that, in other respects, the process is nearly the same with that used in dyeing with cochineal.

"As the colours dyed, even with stick lac, though not quite so beautiful, approach very nearly to those of cochineal; and as there is a great consumption of it, particularly for dyeing red morocco leather, for which purpose it is exported in great quantities to Portugal and Barbary, I think there is every reason to believe that this lake may prove a valuable discovery."

A copy of the preceding communication, with a sample of Mr. Stephens's preparation, were transmitted by the board of trade to the Honourable Court of Directors, with a recommendation (contained in their letter of the 7th of July, 1796,) that the sample in question should "be referred to Dr. Bancroft for examination and his opinion thereof," which (they add) "we request may be communicated to us." And in conformity with this recommendation, the committee of warehouses of the India Company, sent me, on the 8th of February, 1797, the samples of Mr. Stephens's preparation, with copies of the papers relating to it, and a request that I would inform them of the results of any experiments I might think proper to make therewith; and in particular "how far it might be adviseable to import any quantity, and to what extent such importation might be carried, and what might be its relative value, compared with cochineal."

According to my best recollection, the preparation made by Mr. Stephens was in the form of

a *powder*; and though it was not without some defects, my opinion and report of it were, I believe, generally favourable; but I cannot find any copy of the report itself, which probably has shared the fate of the papers respecting East Indian cochineal, mentioned at p. 445 of the preceding volume.

Such was the origin of a species of manufacture or preparation, which (with a change of its form, to that of *cakes*, like those of indigo) has been lately carried to a very considerable extent in the East Indies, and thence brought to this country, in large quantities, under the name of *lac lake*. Indeed the sales of it, at the India House, within the last three years, have been so great, that in point of colouring matter, the quantity sold would have nearly equalled half a million of pounds weight of cochineal; but as it was prepared by different persons, with some variations in the quality, and as in all of it, the colouring matter was encumbered and deteriorated by other matters, partly extracted therewith, and partly added, to cause a precipitation of the colouring matter, so much difficulty and uncertainty attended the employment of the lac lake, that after having been sold to profit for some time, it ceased to find purchasers, even at a fourth part of the price which it would have brought, if the colouring matter had not been so deteriorated; and the scarlet dyers in the year 1810 were

generally determined to abstain from the use of it. Unwilling that a matter which seemed capable of being rendered highly beneficial to the public, as well as to individuals, should be lost, I was induced to enter upon a series of experiments, not only with the lac lake, but also with the lac colouring matter in its natural state, for the double purpose of removing or correcting those defects which had obstructed the use of the *former*, and of discovering better methods and means of extracting and concentrating the *latter*, than any which then appeared to have been employed for that purpose in the East Indies.

That I may abridge the account, and avoid the details of a part of my experiments, I beg leave to refer those who desire more information concerning the constituent parts of *stick* lac, to Mr Hatchett's "Analytical Experiments and Observations on Lac," printed in the Philosophical Transactions for 1804, which, (though I am not prepared to adopt some of his inferences) will afford the best information yet published on that subject, and shall content myself with observing, that besides the colouring and other *animal* matters, composing or proceeding from the insects and their eggs,* *stick* lac, separated from the

* Mr. Hatchett seems to have confounded all these *animal* matters (including even the insects) under the denomination of *Gluten*, and excepting only what he calls "colouring extract."

wood, consists of a *resin* very much resembling that produced by the hymenœa courbaril (commonly called gum anime) and that denominated copal, together with a small portion of a species of wax, possessing most of the properties of myrtle wax, obtained from the berries of the myrica cerifera. In the greater part of the stick lac which I have tried, this resin has appeared to amount to about two-thirds of the whole, but it is always in a lesser proportion when the colouring and other animal matters are most abundant; and these are liable to such variations, that some pieces of very dark stick lac have, in my experiments, afforded as much colouring matter as a sixth part of their weight of fine cochineal, whilst other pieces of a light amber colour would only yield as much as a fifteenth part. Judging, however, from the samples which I have tried, I conclude, that stick lac, as commonly imported, contains nearly as much colouring matter as one-tenth of its weight of cochineal.

It seems probable, that if the lac insects in their different states, and their eggs, could be divested of, or separated from, the resin composing their cells, and distinctly collected, without any extraneous or useless matter, they would afford as much colour, and prove as valuable, as an equal weight of cochineal. But their utility and value to mankind are greatly

diminished by the strong and very hard covering by which they are naturally surrounded and protected, instead of the farinaceous and filamentous clothing of the cochineal. It is, indeed, true, that the resin composing the cells of the lac insects, may be dissolved by alcohol, and by the several alkalies; but the former solvent would prove too costly, and both it and the alkalies would, at the same time, dissolve the colouring matter, and render it, in a great degree, useless to the dyer, by confounding and uniting it with the dissolved resin; and it has, therefore, been deemed expedient to break the cells of stick lac mechanically, by pounding or grinding; but when this has been performed, it is found that water, which is the most proper *menstruum* for *adjective* colouring matters, (and the only one capable of dissolving that of the lac insect, without, at the same time, dissolving something hurtful or inconvenient to the dyer) will, according to my experiments, extract but a very limited portion of *that* which is under consideration; for having several times mixed water in a close vessel with a very great *superfluity* of the *richest* stick lac in powder, and kept them during twenty-four hours in a sand bath, at the heat of nearly 200 degrees of Fah^t^. and afterwards decanted the clear liquor, I could never find that the latter, however small its proportion might be

to the lac, had retained in solution more colouring matter than was equivalent to two grains of cochineal for each ounce of water, unless the latter had been partly evaporated after being saturated with colouring matter. It was, probably, this difficulty of extracting the colouring matter from stick lac, without a very great proportion of water, (even when boiling) that induced the manufacturers of lac lake to increase its solvent power, by adding alkalies to it, particularly soda, an addition which was not proposed by Dr. Roxburgh, nor, as I believe, practised in the earliest preparations of that drug: but it has, unfortunately, enabled the water, besides the colouring matter, to extract and unite with the latter so much of the resin* as is sufficient, when afterwards precipitated by alum, to render the lac lake completely insoluble by water, and nearly so by the acids commonly employed in dying scarlet. It may, indeed, be dissolved by *all* the alkalies; but when so dissolved, the colour will not attach itself to the cloth, unless the acids in

* Mr. Woodcock, who, beneficially for the East India Company, (as I believe) performs the duties of Inspector of the Cloths dyed for their account, has informed me that, according to his experiments, the greater part of the lac lake, as commonly prepared, contains about one-third of its weight of resinous matter; and this is nearly the result of my experiments.

the dying liquor are sufficient in quantity to *predominate* over the alkalies; and when this is the case, the resinous lac lake will immediately curdle, and form little masses, which, by retaining a great portion of the colouring matter, render it useless. These resinous masses, also, being in some degree liquified by the boiling heat of the dying liquor, have frequently attached themselves in small *patches* to the cloth, so firmly, that nothing could afterwards remove them, without injuring either the cloth or the scarlet colour which it had received. It seemed, therefore, highly important to discover better means or methods of extracting and collecting the colouring matter of lac, so that it might be presented to the dyer in a form which would render its use as simple and convenient as that of cochineal: and I therefore made a great number of experiments, not only to attain this object, but moreover to ascertain, whether, in all the strictness of truth, the colour of the lac insect, when employed to dye scarlet, could be made to equal that of cochineal in lustre and vivacity, as a persuasion to the contrary had long been prevalent, and supported by very respectable authorities, particularly those of Hellot and Berthollet, of whom the former, in admitting that the scarlet dyed from lac is *more durable* than that of cochineal, represents it as not possessing equal vivacity, *(" éclat").* (See

Art de la Teinture, &c. chapt. xv.) Berthollet also says, " La couleur qu'on obtient de la laque n'à pas l'éclat d'une écarlate faite avec la cochenille, mais elle à l'avantage d'avoir plus de solidité." (Elements, &c. tom. ii. p. 204.)

In opposition to these and other authorities, I soon convinced myself, that the colour of the lac insect was capable of producing effects similar to those of cochineal, with the various preparations and combinations of tin, (so amply described in the preceding chapter,) and that, even with the common dyer's spirit, or nitro-muriate of that metal, and tartar, it might be made, at least on a small scale, to dye scarlets, equal in vivacity and beauty to any which have been produced from cochineal, and by the same means, taking care only to employ them *in a proportion somewhat larger*. The ascertaining of this fact, I considered as a matter of some importance, for if the colour, as it exists naturally in the stick lac, had been incapable of producing a scarlet sufficiently bright and lively, I could not have hoped that it would be improved in that respect by being separated and collected in the form either of an *extract* or a *precipitate*.*

* The lac lake appears to partake more of the nature of a *precipitate* than of an *extract*; the colouring matter, after it has been dissolved and separated by boiling, or hot water, with the assistance of soda, being precipitated by alum; which, more-

In the course of my experiments I discovered, that water, when at the common temperature of the atmosphere between the tropics, would

over, by its sulphuric acid, neutralizes the soda, and throws down the *resin*, (dissolved by the latter) in combination with the colouring matter. The precipitate so obtained, besides other matters, which at best are useless, contains two, which are hurtful; for, in addition to the resin, (the ill effects of which have been already noticed) it retains a considerable proportion of alumine, which, when employed as a basis for the lac colour, produces on woollen cloth only a dull red, greatly inferior even to that commonly dyed from madder with alum. It is, indeed, true, (as I had discovered twenty-five years ago, and noticed at p. 232 of my first publication on this subject) that the oxides of tin, by their superior attraction for the lac colour, (as well as for that of cochineal) will decompose and separate the latter from any combination with alumine, (and even with iron) so as to obviate that degradation of colour, which either of these would otherwise produce. But to obtain this effect, the oxide of tin must be employed so *copiously* as to *saturate completely the affinities* of the colouring matter, which will only relinquish its attachment to the alumine, (or the iron) in proportion as it is adequately supplied with a *more attracting* basis, and, therefore, though the ill effect of an aluminous *precipitant* for the lac colour, may be overcome, it is desirable that it should not be employed without necessity.

It is said, by well-informed persons, that the manufacturers of lac lake moreover employ a small portion of the powdered bark of a shrub, there called *atour* bark, which they mix with the solution of alum, intended to precipitate the lac colour. It will be recollected, that Dr. Roxburgh, (as was mentioned at p. 14 of this volume) after describing the process recommended by Hellot for effecting a precipitation of the colouring matter of lac by alum, and a decoction of comfrey root, pro-

dissolve and extract almost as much of the colour of powdered stick lac, as when assisted by a boiling heat; a fact never suspected, as I believe, by any other person, and of considerable importance to those who may engage in the business of separating the colour from stick lac, as it will enable them to avoid the expence of fuel, to which the preparers of lac lake appear to have hitherto subjected them-

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poses, as a substitute for the latter, to employ a mucilaginous decoction of the seeds of the *cassia tora*, Lin., and I suspect this to be the shrub from which the bark called atour bark is taken; but whether this suspicion be well founded or not, I confess myself unable to conceive any benefit likely to result from this addition. Hellot found, that though alum would precipitate the colour when suspended in water; yet, when he endeavoured to collect the precipitate by filtering, the water which passed the filter carried with it more colour than he was willing to lose, and he imagined, that a mucilage of the comfrey root helped to obviate this waste, by obstructing the pores of the filter. But in preparing the lac lake no such purpose is to be answered, the soda which is employed, and resinous part of the lac curdled by the alum, forming so complete a precipitation, that the clear supernatant liquor may be sufficiently drawn off, without any separation by the filter.—Possibly the atour bark may contain *tannin*, and as the lac insects afford a small portion of animal jelly, (gelatine) through less than cochineal, this tanning principle might coagulate the gelatine, and thus help to precipitate with it the colouring matter, if any such help were wanted, which to me does not seem probable.

selves.* I discovered, also, that water of this (common) temperature, extracted the colouring matter *unincumbered* by a portion of other useless animal matters, dissolved by it when boiling; and having carefully evaporated a few quarts of this cold infusion of powdered stick lac, made during some warm days in the early part of September, I obtained an extract, which, when dried and rubbed in a mortar, broke readily into fine powder, and was afterwards found to dissolve almost as speedily as refined sugar; and having tried this powder to dye small pieces of broad-cloth, with the usual mordants, I had no difficulty in producing therewith scarlet colours equal to the best which could be any where found, and with little more than half

* Stick lac ought never to be subjected to the action of *boiling* water when the colouring matter is intended to be extracted; for at the heat of 212 of Fah[t]. the resinous matter composing its cells, will be so far liquified, that their partitions, if unbroken, will cohere, and by inclosing the insects and their eggs, will render their colouring matter inaccessible to the action of water; and even when the cells have been destroyed, as in finely powdered lac, the fragments of the insects, with their eggs and colour, will be so far confounded and involved with the liquified lac, as to be thereby *protected*, and rendered insoluble by any thing which does not previously dissolve the resin, and, by so doing, render the colour unfit for the dyer's use. But this liquefaction will not take place whilst the heat is less than 190 degrees of Fah[t], which it ought, therefore, always to be, when we wish to obtain the colouring matter of stick lac.

as much in weight of the powder as would have been required of cochineal to produce similar colours. This powder, which at the actual price of cochineal, would have been worth nearly three guineas the pound, seemed to consist, almost exclusively, of pure colouring matter, and to be capable of answering every purpose which could be desired, or at most to be only objectionable from the circumstance of its requiring an evaporation of the water, instead of being more expeditiously separated from it by precipitation. But I thought it desirable to collect and produce this matter, in a state which would admit of its being readily dissolved by water; and this could never be the state of a precipitate from water; for the means which must have caused the colouring matter to separate itself from its aqueous menstruum and *subside*, even while *moist*, would necessarily render it insoluble by a similar menstruum, after being dried. I was moreover convinced, by the extraordinary effects which I had witnessed from a species of machinery which I formerly erected at Brentford, for the purpose of evaporation, and by which a prodigious multiplication of surfaces, with a rapid motion of the air, were produced,* that no

* A principal, and I believe *novel,* part of this machinery, consisted of a wheel resembling, in most particulars, that of

very considerable difficulty or expence would attend this mode of preparation, especially

an undershot water-mill; but instead of *float boards*, its whole circumference was covered or surrounded by a strong, coarse, porous horse-hair cloth, three feet in width; within this were placed two other circles or circumgyrations of the same hair-cloth, at the distance of twelve inches from each other. The axle of the wheel was placed so that the outer circumgyration of cloth, three feet in width, at every turn of the wheel, was, through its whole surface, immersed several inches in the fluid to be evaporated, which was contained in a very large shallow leaden pan, fixed upon cast iron plates, and heated by a fire below; and this cloth, in making the rest of its circuit, after passing through and taking up the hot liquor, constantly let a considerable part of it fall in drops upon the inner circles of cloth, from which it ultimately descended into the pan. The wheel also, at its opposite and most distant extremities, threw off some of the fluid through which it had passed, and this was received by walls constructed for that purpose, and heated by *flues* from the *fire under the pan*. These walls were covered by sheet lead, which was made to carry back into the pan the fluid thrown upon it.—But this not being sufficient, a small pump, worked by the same power which turned the wheel, was made to raise, and by the help of pipes, with suitable perforations, to distribute *more* of the fluid over the whole surface of these leaden coverings, from which it constantly trickled down into the pan. By these means the surface of the fluid to be evaporated was vastly multiplied, and the motion of the wheel, with the warmth between its partial inclosure, occasioned a constant application of dry or fresh air to the dispersed fluid; and this, if it had been required, might have been at any time greatly increased by applying the *centrifugal* bellows, described by the late Mr. Desaguliers, in the 39th vol. of the Phil. Transactions. When the fluid in the pan began to acquire

when assisted by the very *hot* and *dry* atmosphere which prevails in the East Indies during a great part of the year; and considering the abundance as well as the low price of stick lac in the East Indies, I was convinced, that this mode of extracting and importing the colour of the lac insect, might supersede the use of cochineal in Great Britain, and afford the means (so much wanted) of remitting several hundred thousand pounds annually from India, with the additional advantage of substituting a *cheaper* production of *British* India for one derived almost exclusively from *Spanish* America.

Under this conviction, I (in October, 1811) addressed a Letter to the Chairman of the Court of Directors of the East India Company,

consistency, and *approach* to the condition of a moist or soft extract, it was removed, and the evaporation completed by an apparatus, which I need not describe, because its purpose might be speedily and beneficially effected in the East Indies, by a simple exposure to the sun and dry air, with proper *stirring* to break or obviate the formation of a crust or pellicle on the surface, which last should be as much *extended* as it can be without inconvenience. The fire might also be spared in that climate, and a wooden vat substituted for the *pan*, unless the fire should be found necessary to hinder the commencement or progress of a putrefactive process, to which the *animal part* only of the stick lac is liable. Fortunately, however, the colouring matter of this insect, like that of the cochineal, is not injured by a small degree of putrefaction.

offering to communicate what I considered as important on this subject; but, at the same time, intimating, that as I had been in a great degree frustrated of the fair advantages of another discovery, (to be mentioned hereafter) I could not, on this occasion, exercise that liberality to which I had been inclined and accustomed in regard to my discoveries, and must hope for a reasonable, though moderate, remuneration for the advantages to be derived from the proposed communication. This letter, accompanied by samples of *very fine scarlet* colours, which I had dyed from the preparation before-mentioned, having been referred to the Committee of Directors for *buying*, (to which all matters connected with dying are submitted) I was requested, by that Committee, (previously to a final determination on the proposition contained in my letter) to dye a piece of *long-ell*, (the woollen cloth of which the Company's exports are chiefly composed) from *stick* lac, to be supplied, together with the cloth, by the Committee, in order, as was afterwards explained, to establish the practicability of producing good scarlets from the colour of the lac insects upon *whole* pieces of cloth; the samples which I had sent having been taken from *small* bits of cloth. In compliance with this request, I, on the 25th of January following, dyed *six* pieces of the Company's long-ell cloth, at the dye-

house of Messrs. Barchard and Co. at Wandsworth, (by whom a very considerable part of the Company's scarlet cloths are dyed) solely from stick lac, which had been sent to them by order of the Committee; and I found no difficulty in producing from it, with only the common mordants, (furnished by Messrs. Barchard) a scarlet colour, in every respect equal to that dyed upon similar cloths from cochineal, by the same mordants. This operation was performed in the presence of very competent judges, who unreservedly approved of the colour, as the Committee did afterwards, when the cloths were returned to them by Messrs. Barchards, with an affidavit from me, stating that, according to my best knowledge and belief, no colouring matter had been employed in that operation, excepting that of the stick lac furnished by the Committee, to which, indeed, I had had no access, but in the presence of witnesses.

'The practicability of substituting the colour of the lac insect for that of cochineal, and of producing therewith scarlets equally beautiful, (and more durable) being thus *established*, I was requested by the Committee to prosecute the subject, by preparing a sufficient quantity of the extract, which I had proposed as a substitute for cochineal, and dying with it a piece of the long-ell cloth,—and accordingly, I soon

after (by infusion) impregnated about twelve gallons of water with as much of the colouring matter of stick lac as I could conveniently make it dissolve, and requested those respectable Chemists and Druggists, Messrs. Corbyn and Co. to allow it to be evaporated in their elaboratory, and under the care of their operator; to which they readily and obligingly consented; unfortunately, however, it appeared, after the evaporation was finished, that the fire had not been sufficiently moderated in the concluding part of the operation, and that a portion of the extract was in some degree charred, or carbonized, and thereby rendered insoluble; and that the other part had suffered injury from the heat, though in a less degree. I determined, therefore, not to employ this preparation; but make another, substituting only a *vapour* bath for the *naked* fire, by which the first had been evaporated, and in this last there was, I believe, no combustion, as I found it readily soluble by water; but Mr. Corbyn, (who, knowing the purpose for which the extract was intended, had paid particular attention to it) informed me, that he had noticed a sudden and remarkable diminution of the beautiful colour of the liquor, when it began to acquire a little of the consistency of a soft extract; and I found afterwards, that the colour which it produced by dying, was deficient in brightness or vivacity, but not to such

a degree as to deter me from making a trial of it, though I previously intimated to the Committee, (by letter, addressed to Mr. Davison) my apprehension of a want of success; an apprehension which was verified by an experiment made on a single piece of the long-ell cloth, at the dye-house of Mr. Stevenson, in Brick-lane, Old-street, on the 16th of March, when the colour produced was so far deficient, that I requested Mr. Woodcock to consider and report the experiment as one which had failed.

Twenty years ago, Fourcroy had noticed and mentioned, (in the 5th vol. of the Ann. de Chimie) the strong disposition of the aqueous extracts of several colouring matters to attract from the atmosphere, and combine with large proportions of oxygene, and thereby acquire new properties; and I had witnessed this effect in making the extracts of different vegetable colouring matters, particularly that of logwood, even when the heat employed was less than that of boiling water, at which, or rather beyond it, most organized bodies, whether animal or vegetable, are liable to decomposition: I, therefore, concluded, that even the last extract, made at the elaboratory of Messrs. Corbyn and Co. must have been injured in the former or latter of these ways, though that which I had before prepared on a smaller scale, and which therefore was subjected to the action of heat for a shorter

time, had received no injury; and it being impossible in this climate, and at that season of the year, (which had been uncommonly wet) to produce an extract by evaporation, with *only* the heat of the sun, and the aid of a dry atmosphere, as might be done in the East Indies, and, consequently, impossible by any experiment *here* to ascertain how far the preparation in question might be advantageously made in the country where *alone* I had proposed that it should be made, I resolved to leave that question to be decided by *future* experiments in the East Indies, and in the mean time to endeavour to ascertain how far it might prove advantageous to *collect* the colouring matter of lac, by *precipitating* it, from its aqueous solution, *not by alum*, according to the present practice, but by the *oxide of tin*, which would afterwards afford the only proper basis of a scarlet colour, instead of the improper one, to which it has been hitherto united by the manufacturers of lac lake. I had previously found, by repeated experiments, that tin dissolved either by the muriatic or nitro-muriatic acids, would occasion a very copious precipitation of the lac colour, and that, after letting off the clear superincumbent water, the precipitate might be completely separated from all the remaining moisture, by suspending it in close linen bags, as is done with indigo, and after-

wards drying it in the sun, and even in the shade. The muriate of tin has seemed to act rather more efficaciously than the nitro-muriate as a precipitate, and it possesses the advantage of being also the cheapest. One pound of muriate of tin, in which the acid of the ordinary strength (1170) was *saturated* with the metal, and which in London would cost about one shilling, appeared capable of precipitating as much of the colouring matter of the lac insect, as, *in its effects,* would be equivalent to one pound of cochineal; and though this might a little exceed the cost of the alum required to produce an equal precipitation, it would ultimately prove cheaper, because the oxide of tin would be all preserved, and being dissolved by the proper acids, would serve, in dying scarlets, as a basis to the colouring matter, without the help of any other, or more of the solution of tin.* Convinced of these facts, I, about the

* There would be no difficulty in preparing the nitro-muriate of tin, at least in the East Indies—that metal, of the purest quality, being found at Banca, Malacca, &c. and salt-petre being there much more abundant and cheaper than in Europe. This last may be advantageously decomposed by argillaceous and ferruginous earths, and its acid thus obtained by distillation, without any intermixture of sulphuric acid; a circumstance of no small importance, for the reasons mentioned in the preceding chapter,—and the nitric acid being obtained, it would only be necessary to add sea salt to produce the nitro-muriatic.

end of May last, precipitated by the muriate of tin as much of the lac colour as, according to my estimate, would be more than sufficient to dye a piece of the long-ell cloth. But in trying it, I wished also to make an experiment with the lac colour in a more *simple* state, that a comparative estimate might be formed of their respective advantages. I had some months before sent a few pounds of the stick lac, separated (from the wood) to Mr. J. Bell, Druggist, in Oxford-street, to be pounded; and wanting some of it *immediately* for an experiment, I requested that he would cause a part only of it to be powdered, and sent back as soon as possible, keeping the remainder to be done at his own convenience. Accordingly, I soon received back from him about one-third of the quantity which had been sent, and was agreeably surprized to find that it afforded much more colouring matter than I had expected; but having occasion afterwards to employ the remaining two third parts, I, with equal surprize, found it to be almost destitute of colouring matter; which led me to suspect that some mistake or improper mixture had been made. Mr. Bell, however, accounted for the difference between the first and second parcels, by assuring me, that the man employed to powder the lac had at first subjected the *whole* of it to the action of the pestle for a short time, and had then sepa-

rated the finer part for my immediate use, by sifting it. This information having excited my particular attention, I made several experiments, which confirmed Mr. Bell's explanation, and proved, that the darker and richer pieces or parts of the stick lac, being always most replete with the cells, bodies, and eggs of the insects, were constantly broken by the pestle, sooner, and with much greater facility, than the more solid amber-coloured pieces, containing but few cells or insects, with but little colouring matter; and that by sifting the lac from time to time, whilst under the operation of pounding or grinding, a portion of it, equal in weight to about one-fourth part, when the lac is of good quality, might be separated, which portion would contain at least three-fourths of the colouring matter of the *whole* original quantity; and that the remaining fourth part might, be dissolved or extracted by water, of the common temperature of the atmosphere,* in the East Indies, and superadded to the powder, containing the other three parts, by spreading the latter in a situation where it would be fully exposed to the sun's rays, and sprinkling or impregnating it, from time to time, with the water containing the dissolved colour, until the whole shall have been thus superadded and

* After this extraction of the colour the residuum would be seed lac, of a very good quality.

evaporated, as would there be in a very short time.

By this process three pounds of the powder (resulting from it) might easily be made to contain and yield the colouring matter in its *best* state, of ten or twelve pounds of lac, separated from the sticks; and it was this preparation which I proposed to try, in order to compare its effects with those of the lac colour precipitated by the oxide of tin. Accordingly, I separat d by sifting, from eleven pounds of ordinary stick lac in powder, about three pounds and one quarter of the finer part, which, by an experiment upon a small scale, appeared to contain nearly as much colour as one-third of its weight of cochineal. I did not, on this occasion, think it necessary to take the trouble, or incur the delay, of extracting the colour of the remaining seven pounds and three quarters, and of superadding it to the former, as just described, by *evaporation*, (for which this climate is but little suited) having previously and satisfactorily performed this part of the experiment upon a smaller parcel.

With each of these preparations, an experiment was made at the dye-house of Mr. Stevenson, on the 15th of June, 1812, in the presence of Mr. Woodcock, who attended in behalf of the Committee; but neither of them fulfilled my expectation in regard to the *quan-*

tity of colouring matter afforded by it. The piece of long-ell cloth dyed from the *sifted* lac, took, indeed, a scarlet colour, which was liable to no objection, but that of its wanting a little more body or fulness, to make it appear to the utmost advantage; and this defect I then supposed, and have since ascertained by repeated experiments, to have resulted from the shortness of time and insufficient quantity of water employed to dissolve and extract the colouring matter. In my own smaller experiments, I had put the sifted lac to soak or macerate during the preceding night, with a copious allowance of water; but this precaution was wholly omitted in the experiment under consideration, because I wished that nothing might be done in the absence of Mr. Woodcock; and in consequence of this omission, the colouring matter of the sifted lac was not extracted so as to produce its full effect; otherwise being, as in the former experiment at Wandsworth, in its *natural* and *best* state, its effects must have been, as on that occasion, *perfectly* satisfactory.

In regard to the piece of cloth for which the lac colour, precipitated by muriate of tin, had been employed, there was, I believe, no reason to conclude that a scarlet sufficiently bright would not have been produced, if an adequate portion of colouring matter had been applied to the fibres of the wool; and several causes

presented themselves to my mind as capable of having produced this deficiency,—of these, the most obvious was that of a considerable part of the precipitate being left at the bottom of the dyeing vessel *undissolved.** This I mentioned to Mr. Stephenson (as well as to Mr. Woodcock) at the time, and proposed to draw off the upper part of the water, so as to examine the sediment; but I was told, that the particular vessel in which this experiment had been made could only be emptied by lading the water upwards, which would necessarily cause too much agitation for my purpose. There was another cause, which seemed probable, from recollecting the fact mentioned in the preceding chapter, of the action of tin, when much oxygenated, upon the colouring matter of cochineal, which, in regard to its effects, is thereby in a considerable degree diminished, or made latent. I then thought it likely that, in drying the lac precipitate, by the heat of a fire, the oxide resulting from the

* The precipitate in question being like *all* others, necessarily insoluble by water alone, I had, in my own experiments upon the small scale, commonly rubbed it in a glass mortar with a little diluted muriatic acid and tartar, and left them afterwards to macerate during the following night; but this precaution, like that in regard to the *sifted* lac, (recently mentioned) was omitted, and for the same reason, joined to the expectation which I then entertained, that the acids in dying liquor would suffice to dissolve the precipitate, during the operation.

muriate of tin, had (as it is always strongly disposed to do) acquired such an addition of oxygene from the atmosphere, as to occasion the disappearance of a part of the colour. To ascertain the truth on this point, I macerated a portion of stick lac in powder, with a suitable quantity of water, and having afterwards strained off the clear infusion, I divided it by *measure* into two equal parts, from one of which I dyed, with the usual means, a certain quantity of broad-cloth, adding more of the latter, until I had completely *exhausted* the colour; and having precipitated the colouring matter of the other half, by the muriate of tin, and dried the precipitate (in the same way as I had done that employed on the 15th June) I afterwards dissolved the precipitate so dried, by diluted muriatic acid and tartar, with which, (and without any other mordant) I dyed an equal quantity, by weight, of the same broad-cloth, and found the scarlet thus produced was in every respect equal to that which had been previously dyed by the lac colour in its best state; and, consequently, that this mode of precipitating the colour had not caused the deficiency in question. In addition to these, there was a *third* cause, which might be suspected of having operated in producing this deficiency, which was the insufficiency of the water employed to dissolve and extract the colouring matter of the lac.—I had not, in

making the precipitate, properly attended to this circumstance; but when I came afterwards to reflect and calculate, I found that the quantity, as far as I was able to ascertain it, must have been too small to dissolve so much of the colouring matter as I had supposed to have been extracted and precipitated for the experiment in question; and I found also, that this must have happened in regard to the extract prepared by the operator of Messrs. Corbyn and Co. for the experiment of the 16th of March, for which twelve gallons only of the aqueous solution were sent to be evaporated; and my experiments having shewn, that each gallon of water will only extract colouring matter equivalent to half an ounce and a few grains of cochineal; and ten ounces of the latter being required to dye a piece of the long-ell cloth, it must be inferred, that the quantity of lac colour employed for that experiment was much too small to produce the desired effect.

That the first and the last only of the three causes, just mentioned, occasioned the deficiency of colour afforded by the *precipitate* employed on the 15th of June, has been since proved, by experiments made upon a small scale, with a sample of that precipitate, which had been preserved, and which being properly dissolved by a little diluted muriatic acid and tartar, and employed in the same proportion as it had

been on the 16th of June, was found to produce much more effect, than that which was then produced, though it did not dye a *full* bright scarlet, until it was employed in a proportion, *greater by at least* fifty *per cent.* Similar results were produced by a part of this sample, which had been macerated with an equal weight of carbonate of soda in water, by which the colouring matter was nearly all dissolved and separated from the oxide of tin, and the clear solution being poured off, it produced, in a similar proportion, a very good scarlet, with the nitro-muriate of tin and tartar, employed a little more freely, indeed, than is usual, in order to neutralize the soda.

In regard to the extract prepared by the operator of Messrs. Corbyn and Co. which was tried on the 16th of March, I beg leave to add, that I did then suppose that it must have suffered some injury during the evaporation, by an absorption of oxygene in the concluding part of the operation, as frequently happens to vegetable extracts; and wishing to ascertain the truth on this point, I, on the last day of the year 1812, took a very small sample, which had been reserved, of that extract, and put it into a glass with hot water, and twice its weight of sugar, (which I had found to be very efficacious in the *de*oxygenation of indigo) and having rubbed these until both were dissolved, I left

them together during twenty-four hours, and then employed them in dying a bit of broad-cloth with nitro-muriate of tin and tartar, and had the satisfaction of thus producing a very fine scarlet, equal to almost any which can be obtained from cochineal. This experiment seemed to prove, at least, that the lac colour had suffered no *irreparable* injury by being evaporated, and brought to the form of a dry extract; but it did not prove that the colour, though much better than I had formerly produced with the same extract, had been improved by the *deoxygenating*, or any other influence of the *sugar;* and being anxious that no uncertainty should subsist in regard to this fact, I, on the 4th of January, 1813, applied to Mr. Woodcock at the India House, and obtained a small part of a sample of this extract, which had been reserved for the Committee, and with this I made another experiment, similar to the former, excepting the sugar, which was omitted, and I found, unexpectedly, that the scarlet then produced, was so nearly equal to the former, that I could no longer ascribe any considerable benefit to the sugar. I found, indeed, that the colour did not acquire its utmost brightness until I had employed a greater proportion of nitro-muriate of tin and tartar than is commonly employed with cochineal, and a greater even than that which has appeared to be necessary with the lac

colour in its natural state.—Whether this seeming necessity for an increased proportion of these mordants was created by any change which the colouring matter had undergone, by being brought into the state of an extract, I am unable to determine; but I think it probable, that if the same mordants had been *more freely* employed in the experiment of the 16th of March, better effects would have resulted, though, from the deficient *quantity* of colouring matter, a good scarlet could not, I think, have been obtained.

Soon after I had written to the Chairman of the Court of Directors, as before mentioned, a *new* preparation of lac colour, under the name of *lac dye*, was imported by the East India Company, (prepared under the direction of Mr. Turnbull, a surgeon in their service) which, though not exempt from the inconveniences of the lac lake, retained them in a smaller degree, and with the advantage of yielding a greater proportion of colour. This preparation was, however, left unemployed until after my experiment at Wandsworth, had *established* the practicability of substituting the colour of the lac insect for that of cochineal.—But, within a fortnight after this had been done, the Committee of Buying determined to distribute this lac dye, among the Company's dyers, at a moderate price, to be employed in dying their

cloths; and also to allow a portion of the lac lake, to be employed for the same purpose *conjointly* with cochineal; it being found that the difficulties resulting from the insolubility of the former and latter, might be greatly diminished, by *a very minute mechanical division*, or grinding between stones, particularly adapted to that purpose. But in permitting this use of the lac dye and lac lake, the Committee properly required, and obtained, from the dyers, a diminution in the price before paid for scarlet colours, which, in the course of three or four months, had, as I am informed, produced a saving to the Company of fourteen thousand pounds, without any inferiority in the scarlets so dyed, as far, at least, as I have been able to observe, or learn; and though, in a few instances, the cloths were injured by adhesions of the *resinous* part of these preparations, the injury was probably occasioned by their not having been so finely ground as they ought to have been.

This was the state of things when my last experiments were made on the 15th of June, and their imperfect success having occasioned some doubt in my own mind, whether the proposed extract by evaporation, or the precipitate by an oxide of tin, would operate more beneficially, and prove cheaper than Mr. Turnbull's lac dye, which had been supplied at a very mo-

derate price, and it being difficult to ascertain the truth on this point *in this climate*, or, indeed, without trials upon a much more extended scale, in the places where such preparations were intended to be made, I candidly intimated this doubt to the Committee, and determined to publish an account of my experiments and ideas on this subject, and leave their accuracy and utility, to be decided by the only certain test, that of future adequate experience,—and in order to facilitate this decision, I will here subjoin a few additional observations.

Should it hereafter be found advantageous to concentrate the lac colour in the East Indies by *evaporation*, it will be very desirable to increase the solvent power of water, in order to diminish the quantity of moisture to be evaporated. The alkalies are unfit for this purpose, because, as I have already intimated, they occasion a solution of the resin, as well as of the colouring matter of the lac. The nitric acid cannot be employed in this way, because it exerts a *destructive* action, similar to combustion, upon the colour; but this is not the case with either the sulphuric or muriatic acids, which greatly increase the power of water to dissolve and extract the colouring matter, with at most but a very inconsiderable portion of the resin. The sulphuric acid would, however, be preferable in several respects to the muriatic for

this purpose, if it were either produced in the East Indies, or capable of being transported thither without danger. One gallon of this acid, of the ordinary strength, diluted by one hundred gallons of water, would enable the latter, at the ordinary temperature of the atmosphere, to dissolve *ten* times as much colouring matter as it would otherwise do; and the clear solution being drawn off, and one-half as much in weight of lime, as of the acid employed being added, the latter would combine with the lime, and subside to the bottom of the liquor, which would then remain clear, with all its *scarlet* colour suspended therein, and capable of being drawn off without any of the sulphate of lime. This liquor would, however, still retain a small proportion of sulphuric acid, and it is necessary that it should do so, until after this separation from the sediment, for otherwise the water could not suspend all the colouring matter, and a part of it would subside and be lost upon the sulphate of lime; but this separation having been made, the remnant of sulphuric acid should be neutralized by soda* previous to the evaporation, for other-

* I have in this and other places, directed the use of soda, in preference to potash, for neutralizing the sulphuric acid, because I have found the sulphate of soda invariably to operate more favourably in producing a scarlet colour, than the sulphate of potash.

wise it would attract moisture, and even when the colour had been brought to the state of a dry extract, it would be disposed to deliquate, an inconvenience that does not occur when the acid has been completely neutralized; and its being so neutralized, is moreover necessary, to obviate the ill effect which the sulphuric acid might produce, when the extract came to be employed for dying scarlet with the nitro-muriate of tin. When an extract has been prepared in this manner, it will dissolve readily in water, and produce good scarlet colours, with the mordants commonly employed for that purpose.

If *precipitation* should be found preferable to evaporation for separating and concentrating the lac colour, the quantity or proportion of water employed to extract it, will be of little consequence, especially as the water need not be heated.—Among all the substances capable of precipitating the lac colour from its aqueous solution, (of which I find magnesia to be one) alum and the solutions of tin seem to be the most useful. When alum is employed, about half as much carbonate of soda should be added, which will completely throw down all the colouring matter; after which, the colourless fluid may be drawn off, and the precipitate may be suspended in close linen bags to drain, as is practised with indigo, and afterwards dried in

the same manner. Such a precipitate would contain no resinous matter, and though not soluble in water alone, a small proportion of soda would enable that menstruum to dissolve the colouring matter, with a *part only* of the alumine, and the solution so made would, as my experiments have repeatedly proved, dye a good scarlet by the ordinary means, there being no resinous matter to curdle and attach itself to the cloth, and but a small proportion of alumine, which the oxide of tin, by its stronger attraction for the colour, would render harmless. By this method of dissolving and extracting the colour by *water only*, though it be afterwards precipitated by alum, a preparation, richer in colour than lac lake, or even the lac dye, might be obtained, and it would moreover be nearly exempted from the inconveniences with which they have been attended.

It seems probable, however, that a precipitation of the colour, by either the muriate or nitro-muriate of tin, as described at p. 37, would prove both cheaper and better than the latter by alum.

But though I have thought it expedient to state these observations, respecting the means and ways of extracting and collecting the colouring matter of lac, it is my own decided opinion, that the least expensive, most easy, certain, and useful form in which this colour

can be presented to the dyer, is that which I have recently described at p. 40 and 41. Three-fourths of the colouring matter of a given quantity of the lac, will thus be brought into a fourth part of its natural or former bulk, most expeditiously, and with very little labour; and the remaining fourth may be superadded without any perceptible increase of that bulk, and with much *less alteration* than it must suffer by any other mode of preparation: for the drying or separation of the water containing this part of it, being to be performed merely by aspersion upon a dry powder, and an evaporation with only the ordinary heat of the atmosphere, no deterioration or change can take place, like that to which extracts a e liable, in passing from a fluid to a solid state, by the application of artificial heat: and certainly the very small difference of freight, if there should be any, between this preparation and the extracts or precipitates hitherto made, or proposed to be made, cannot amount to one fourth part of the unavoidable expence of making such extracts or precipitates. It is even highly probable, that with a little pains and ingenuity, stones and machinery for grinding the lac, and sieves or bolting cloths of a degree of fineness suited almost exclusively to the passage of the fragments of the insects and their eggs, might be contrived, and em ployed, so as to diminish the bulk of this pre-

paration, much more than I have stated as being practicable.

By importing the lac colour in this form, (of a dry powder) the dyer, to obtain and employ it in the purest and most perfect state, would only find it necessary to soak or macerate the powder, in the ordinary temperature of the atmosphere, or in water a little warmed during winter; putting it for that purpose into bags, porous, and only porous enough, to admit the water to pass and repass freely without the powder. Several of these, partly filled, might be put, a day or two before the colour was intended to be used, into a large cistern, copiously supplied with water, and being there agitated, from time to time, the colouring matter would be gradually dissolved and dispersed in the water, which might be drawn off, and put into the dyeing vessel when wanted, adding more water to replenish the cistern: and this process might be continued until the water was found to extract no more colour; after which, the bags might be emptied into a large tub or cistern, and the powder subjected to the action of water acidulated by sulphuric acid, as lately described at p. 51 of this volume, in order to extract a remnant of the colouring matter, similar to that contained in seed lac, and which appears to have been always neglected and lost by the dyers of India. I had observed twenty-

five years ago, as was mentioned at p. 271 of my first publication on this subject, that cochineal contained a portion of colouring matter, which boiling water could not dissolve, but which was readily extracted by the alkalies; and I have since discovered the same sort of colouring matter in the lac insect, and in nearly the same proportion, of about one-eighth or tenth of the whole, according to my estimate. This, however, cannot, like that of cochineal, be extracted by alkalies, without also extracting a portion of the resin. But it may be quickly dissolved by the help of sulphuric acid, employed and afterwards neutralized, as recently proposed at p. 51 and 52. Though it will not require any subsequent evaporation, as for the preparation there mentioned. When this part of the colour shall have been extracted, the residuum will be of some value to persons who may be disposed to melt and strain it, in order to obtain a substance similar to shell lac.

In addition to what I have already mentioned of the mordants best suited to the colour of the lac insect, I need only observe generally, that the several oxides and combinations of tin, produce effects with it nearly similar to those which have been so amply described in the preceding chapter, as being produced by them with cochineal; but with this difference, that lac bears the action of acids better than the

latter, and that, in order to obtain the brightest and best colours from it, these mordants, or the acid solutions of tin, ought to be employed more copiously than with cochineal. Had this fact been sufficiently known and attended to, the want of vivacity or brightness in the former would not have been so long a subject of complaint.—The oxides of tin having little or no attraction for the fibres of linen or cotton, the latter are as incapable of imbibing a durable scarlet from the lac colour by their intervention, as they are, known to be of obtaining it by them from cochineal.

In regard to the other basis, I have already mentioned that the colour produced with alum from the lac upon *wool* is much *darker*, and *less beautiful*, though more lasting, than that obtained from cochineal, with the same basis; and this is true in regard to *linen* and *cotton*. The lac colour is indeed used by the dyers of India, to give a dull red colour to the *coarse calico* employed for tents and other common purposes, of which I have been favoured with a sample by Mr. Wilkins. And this appears capable of resisting for a considerable time the action of water, sun, and air, but not of soap, to which, probably, it is not often subjected.

The oxide of zinc, when pure, produces bright colours, approaching nearly to scarlet, with the lac. That of antimony produces with

the lac a colour darker than that which it produces with cochineal. The other metallic and earthy bases, however, seem generally to produce, with the former, effects differing but little from those which, in the last chapter, I have mentioned as being produced by the latter, with this exception, however, that the lac colour seems not to be so much darkened by the oxides of iron, or by ammonia, as that of cochineal; and it is probably from this difference, that the lac scarlet has been found less liable to become spotted or stained by mud, sweat, urine, &c. than the common scarlet.

In regard to the greater durability of the lac colours above those of cochineal, I have seen it manifested by a considerable number of trials, in which they have been exposed and contrasted with each other. Indeed, the colouring matter of lac has so much affinity with the fibres of wool, that with a small intermixture of sulphuric or muriatic acid, *without any basis,* it will dye upon cloth lasting colours, much less darker and less vivid indeed than those produced with the oxides of tin, &c.

I have mentioned, in a former part of this chapter, that a part of my experiments had been directed to the subject of *lac lake,* with the expectation of removing the obstacles which had obstructed its use by the dyers. Many of these experiments produced results of little va-

lue; some of them, however, were attended with considerable success; and it is my intention soon to publish a short account of the latter, with instructions respecting the use of the lac lake in dyeing scarlet, upon a separate sheet, for those to whom such instructions may prove interesting. I do not include them in my present work, because it is directed towards objects of *permanent* utility, and I am persuaded, that the facts stated in this chapter will very soon produce such improvements in the form and manner of preparing the lac colour, as must render such instructions useless.

Believing that I have now done all that can be well performed or expected in this climate, and at this distance from the places where the lac is produced, to discover the best methods of collecting and introducing this colour, as well as to promote the use of it, I shall here leave the subject, to be taken up and prosecuted by those in the East Indies, whose pursuits may enable them, by adequate and decisive experiments, to ascertain the comparative merits of the several methods here proposed.

CHAP. II.

Of Prussian Blue.

"Presque tous les arts doivent leur naissance au hazard; ils ne sont "en general, ni le fruit des recherches ni le resultat des combi- "naisons; mais tous ont un rapport plus on moins marqué avec "la Chymie; et elle peut en eclairer les principes, en reformer "les abus, simplifier les moyens & hater leur progres."

CHAPTAL, *Elemens de Chymie.*

THE first discovery of Prussian blue, or prussiate of iron, as related by Stahl, was, like many other interesting discoveries, purely the effect of accident. About the year 1710, *Diesbach*, a chemist at Berlin, wishing to precipitate the colouring matter of cochineal from a solution or decoction, in which it was combined with a portion of green vitriol, or sulphate of iron, borrowed for that purpose from his neighbour Dippel, an alkali, upon and from which the latter had several times distilled an animal oil, and which had thereby become impregnated with the animal colouring part of Prussian blue; consequently this alkali, when mixed with the decoction of cochineal, or rather with the iron contained therein, immediately and most unexpectedly produced a very beautiful blue colour. The experiment being repeated, and always with the same effect, Diesbach availed himself of the

discovery; and this new colour was made known and sold under the name of Prussian blue; and the means of producing it were kept secret until the year 1724, when Dr. Woodward published an account of the process in the Philosophical Transactions.

The cheapest way of preparing this animal blue, is, by burning dried blood, horns, hoofs, tendons, and other animal substances, so as to reduce them to coal; which is afterwards to be calcined with three times its weight of potash in an iron vessel. After about twelve hours of calcination, the mixture generally appears like a soft paste, and then it is thrown into tubs partly filled with water; which last, according to Berthollet, will in part be decomposed by this addition, and a portion of its hydrogene, combining with a part of the nitrogene, contained in the calcined animal matter, will form ammonia, whilst another part of the hydrogene, by uniting with the remaining part of the nitrogene and the animal carbon, will produce the Prussian *colourable* matter: the oxygene of the decomposed water forming carbonic acid. The *colourable* matter being thus produced, and dissolved in the undecomposed part of the water, is poured, or drawn off, and filtered; and afterwards mixed with a solution of three parts of alum and one of sulphate of iron, in a sufficient quantity of water; and thus mixed, the colour-

able matter combines with the oxide of iron, and becoming *blue*, subsides with it to the bottom of the vessel, but commonly appears *green*, from an excess of the oxide of iron.

Care should be taken, however, as Gay-Lusac has observed, not to subject the animal carbonaceous matter to an excessive heat, and for too long a time, for by *over calcination* it will lose its nitrogene, or azote, which is an essential constituent part of the colourable matter.

The oxide of iron, as M. Berthollet observes, may combine in different proportions with the colouring part of Prussian blue. Where it is greatly in excess, the compound will be yellow; but when the oxide is only in a suitable proportion, the colour will be blue. All acids, and particularly the muriatic, are capable of dissolving the excess of iron, so as to bring the compound to the proper state and appearance of Prussian blue. But farther than this, acids have no power of decomposing or dissolving any part of it, unless assisted by heat. The animal colouring part of Prussian blue, (separated from the oxide of iron) is called the Prussian, or Prussic acid, though I think improperly, as it does not possess the properties of an acid. This M. Berthollet admits, but adds, that it acquires them by combining with a metallic oxide, and is then enabled to saturate alkaline properties, (" les propriatés alcalines"). But

this may also be done by oils and resins, with which the *Prussian colourable matter* seems to have more similitude than to acids.

I have just observed, that nitrogene is indispensably necessary to constitute the Prussian colourable matter, and this fact, in addition to that of its never having been obtained for any of the uses to which it is applicable, except from animal substances, intitles me to consider it as of an *animal* nature, though some small portions of it have been discovered in water distilled from the leaves of laurel, and from peach blossoms, and the kernels of apricots. But these, or any other vegetables which may be capable of affording what is called Prussic acid, can only do it by that small portion of nitrogene or azote which they contain, and by which they are, in that respect, assimilated to animals.

Scheele, to whose sagacity and indefatigable exertions chemistry has infinite obligations, made the first great advance towards the full investigation and right understanding of this very abstruse subject; upon which Berthollet afterwards threw considerable light, particularly in a memoir printed in the 15th volume of the Annales de Chymie;—and M. Proust has since contributed very much to extend our knowledge, and rectify our conceptions of this matter, in two other memoirs, published in the same col-

lection, particularly the *last*, in the 60th volume, to which I refer those who desire *fuller* information on this subject; meaning to content myself with stating, as concisely as possible, the more important facts connected with my present work.

Prussian blue, as commonly prepared and sold, contains a considerable proportion of alumine, and very often silex, sulphate of lime, potash, phosphate of iron, and oleaginous ammonia, which may all be considered as extraneous impurities,—when it contains none of these, nor of alumine, it will, if scratched, exhibit the shining metallic, or *coppery* appearance, which commonly attends indigo.

The best Prussian blue made for sale, if finely powdered, and subjected to the action of pure caustic potash in water, may be dissolved, excepting a residuum, which, freed from every thing soluble, by subsequent additions of water, will consist of *red* oxide of iron and alumine, without any remnant of *colourable* matter—and the solution so obtained, being made to crystallize by the proper means, will ultimately afford more than nine ounces of pure crystals of Prussiate of potash for each pound of Prussian blue so employed, leaving in the mother water, according to Proust, alumine, sulphate, and phosphate of potash, and ferruginous alkaline carbonate. The crystals so obtained will be of

a lemon colour, for which, and for their susceptibility of crystallization, as well as for their property of reproducing Prussian blue, with the *red* oxide of iron, Proust says, they are indebted to a certain *invariable* portion of the *black* oxide of iron, which, in his opinion, forms one of their *essential constituent* parts.

When, instead of pure caustic potash, a lye of the common carbonate of that salt is employed with the Prussian blue, a considerable portion of its *red* oxide will be dissolved, in the same manner as in Stahl's tincture of iron, and though the solution is only of a pale yellow colour, it may be rendered blue by the addition of any acid, however pure; an effect which has frequently misled persons, who either did not know, or sufficiently attend to the cause of this effect; for as in this case the *blue* colour is revived without any addition of iron, we may infer, that the preceding disappearance of this colour was not caused by any deficiency of that metal; and Ican only account for it, by adverting to a *fact*, that seems applicable to this, as well as to several other coloured matters, which lose their respecting colours, some by the presence and *predominance* of an alkali, and others of an acid. In this case, the *blue* Prussian colour cannot manifest itself when the colouring matter is combined with an alkali in excess, or even an alkaline earth, (as is seen by lime water) but it

becomes manifest, whenever the alkali is neutralized by an *acid* with a small excess of the latter.

Soda, in its mild and caustic states, acts like potash upon Prussian blue—and this is nearly true of ammonia. Lime-water also, moderately warmed, dissolves the Prussian colouring matter, holding it in solution with very little more of iron than that portion of the black oxide, which Proust considers as an *essential constituent* of the Prussian colourable matter. This fact was first discovered by Fourcroy, and it renders the Prussiate of lime much fitter to ascertain, as a reagent, the presence of *iron*, than the Prussiates of potash, soda, or ammonia.

Scheele first taught us how to obtain the *pure* simple Prussiate, (consisting of nitrogene, hydrogene, and carbone) by liberating it in the *gaseous* form, from an oxide of mercury, (with which it has a greater affinity than with the oxide of iron); but when so obtained, it has none of that *black* oxide of iron, which is essentially necessary to enable it to co-operate in the production of a blue colour; and, therefore, if it be mixed, and allowed to stand in a phial, with the *red* oxide of iron, for months, it will not, as I have witnessed, contract any union therewith, or cease to be as *colourless as water;* but if a little *green* sulphate of iron, containing the *black* oxide, be added to the mixture, a slight bluish cloudiness will soon appear, and this will gradually increase, and at last termi-

nate in a precipitation of *perfect Prussian blue*. This *simple* Prussiate may be easily decomposed, even by the rays of the sun, (which resolve it into carbonic acid, ammonia, and carbonated hydrogenous gas); but when it is in union with that portion of the *black* oxide of iron, which enables it, with the *red* oxide, to form Prussian blue, this fragility, and ready susceptibility of decomposition ceases; and it then becomes, what some have called a *triple* Prussiate, which I beg leave to denominate a *colourable* Prussiate of iron, or the Prussian *colourable matter*, to distinguish it from the other conditions in which it may exist.

It is remarkable, that when the *simple* Prussiate has combined with that portion of the black oxide of iron, which is necessary to render it a *colourable* Prussiate, its affinity protects the oxide from all farther oxidation; so that if it be mixed with the *green* sulphate of iron, in order to make Prussian blue, though the oxide of the latter (which at first exists only in the state of a black oxide, retaining twenty-eight per cent. of oxygene) will gradually rise from the minimum to the maximum of oxidation, (*i. e.* will increase its portion of oxygene from twenty-eight to forty-eight per cent., and by this increase produce that vivid colour which distinguishes the Prussian blue) yet the portion of black oxide, which Proust considers as an

elementary constituent of this colourable Prussiate, will not, at the same time, receive any, even the slightest accession of oxygene, but will continue unchanged, in the condition of a *black* oxide, united to the oxygene, only in the proportion of twenty-eight per cent.

That iron, at the minimum of oxidation, is incapable, whatever may be the proportion, of becoming, or producing, *a blue* with the *colourable* Prussiate, may be demonstrated by several experiments, described by Proust. But the easiest and most simple is that of dropping some of the crystallized Prussiate into a recent diluted boiling solution of the *green* sulphate of iron, where it will cause a *white* precipitation, which Proust calls the *white* Prussiate of iron, and which is of that colour, *only* because the oxide is at the minimum of oxidation; but as *this* (unlike the *elementary* portion of black oxide) retains a disposition to become hyperoxidated, it will constantly absorb oxygene, and gradually pass from the white to the blue colour; an effect which is analogous to some that we have found to happen with indigo, and which occur also to an infusion of galls, when mixed with the green sulphate of iron. I have obtained a similar *white* precipitation, in the same way, by substituting the Prussiate of lime for the crystallized Prussiate of potash; and also by substituting the muriate of iron, recently prepared, for the *green* sulphate; the iron in

both being equally at the minimum of oxidation. I have also gummed this white precipitate, and applied it in *spots* to muslin and cotton velvet, and found it (by absorbing oxygene) to change speedily to a full and most beautiful blue; and this has happened to calico which I had soaked in Prussiate of potash and dried, upon my applying to it, in spots, a diluted muriate of iron thickened with gum—no colour was visible at first, but the spots soon became blue, by absorbing oxygene. But when, to a piece of calico impregnated with Prussiate of iron, in the same way, I applied a diluted nitrate of iron, (also in spots) the production of *blue was instantaneous*, because the iron in the nitrate was already at the maximum of oxydation. I found afterwards, upon soaking the same calico in hydro-sulphuretted water, that the blue spots, by *de*oxygenation, were again made white, and afterwards rendered blue a second time, by immersing the calico in a diluted nitric acid, which restored the oxygene.*

* M. Berthollet has supposed that the *white* prussiate of iron differs from the *blue*, not because it is less oxygenated, but because the sulphuric acid in the *green* sulphate of iron adheres most strongly to its basis, and as a proof of this, he says, that by adding either the muriatic, sulphur*eous*, or phosphor*eous* acids, to the white prussiate, it becomes blue, though neither can be supposed to afford oxygene. But it must have been almost impossible to make such an addition, without admitting oxygene from the atmosphere.

Bouillon Lagrange says, (Manuel de Chimie, ii. 653) that the Prussic acid will decompose the oxymuriatic, by absorbing the oxygene of the latter, and that it will become odourous; and that, in this state, it will precipitate iron of a *green* colour, which green, by the contact of the sun's rays, or by an addition of metallic iron, or of *sulphureous* acid, will be changed to blue; and as these are all *de*oxygenating agents, we must conclude, if the fact be correctly stated, that the *green* colour, in this case, results from an *excess* of oxygene, and that it is changed to blue by an abstraction of that excess.

The uncommon beauty and lustre of the Prussian Blue, have occasioned many endeavours to apply and fix it equally and permanently as a dye. The late Mr. Macquer first proposed two methods of doing this; but neither proved successful. In one he soaked the stuffs in a solution of alum and sulphate of iron, and then in a diluted Prussiate of potash; and lastly, in water a little soured by sulphuric acid, in order to dissolve and remove any superfluous oxide of iron. By doing this repeatedly, he produced a very beautiful blue colour; but it took unequally, and the texture of the silken and woollen stuffs was rendered very harsh.

In Mr. Macquer's second process the stuffs to be dyed were boiled in a solution of alum and tartar, and afterwards in water, containing

Prussian blue, which had been finely powdered. In this, however, the colouring particles were only suspended, without being dissolved, and therefore, though they were applied to the fibres of the stuffs, it was without any chemical union, and so *sparingly* as only to produce very faint shades of colour.

The Abbé Menon recommended a different process for dyeing linens and cottons with the Prussian blue. They were first dyed black in the usual way, with a ferruginous basis; and then soaked a few minutes in a diluted Prussiate of potash; after which they were boiled in water with alum, and took thereby a deep blue. In this case the Prussian colouring matter, assisted, doubtless, by the acid of the alum, seemed to exert a strong attraction upon the oxide of iron contained in the black dye, and thereby to decompose and separate the vegetable colouring matter, (of galls, &c.) and in its stead to combine with the ferruginous basis; but the colour took unequally.

Some years since, M. Roland de la Platriere* published among the "Arts et Metiers" of the Royal Academy of Sciences at Paris, an account of another method practised at Rouen for dyeing with the Prussian blue, in many respects

* This gentleman, divested of the name of *La Platriere*, was one of the ministers of the French Republic, in the early part of the Revolution, and, perhaps, one whose conduct was the least exceptionable.

similar to Mr. Macquer's second process; but with this difference, that the Prussian blue in fine powder was suspended, not dissolved, by a diluted muriatic acid, instead of pure water; a change which seems to have been attended with some advantage, though it was with difficulty, and not without many precautions and tedious operations, that an equal colour of sufficient body could be obtained; and then, though highly beautiful, it was not in a state of chemical combination with the fibres of the cotton velvets, for which it was principally used, and therefore was liable to be easily abraded by wearing and friction, especially in those places where it had been folded. Air, however, did not weaken the colour in any degree, nor was it injured by acids.

A little time before this, M. le Pileur d'Apligny announced to the world, that he had discovered the means of dyeing a blue, as far exceeding all other blues in beauty and lustre, as the cochineal scarlet exceeds the common reds. He, however, kept his process secret, until the offer of a premium induced him to make it public. He began it by impregnating the stuffs to be dyed with an iron basis, which he prepared by deflagrating equal parts of old iron and saltpetre in a crucible, afterwards washing the residuum, and dissolving it in vinegar and bran-water. This being sufficiently diluted, was applied as a mordant, in the usual way, to the

stuffs, which were afterwards well rinced, and dyed in a preparation of Prussian blue, made by dissolving two pounds thereof (in the moist state in which it is first precipitated) by half a pound of potash, in boiling water, and afterwards adding three ounces of common oil of vitriol, or an equivalent portion of nitric acid, so as to neutralize the alkali, without precipitating the colour. A sufficient quantity of this put into a dyeing vessel, with hot water, and the stuffs, previously impregnated with the iron mordant, being dyed therein, they became at first green, and afterwards of a beautiful blue colour; which was, however, still liable to take unequally, and, therefore, M. d'Apligny's process, as far as I can learn, has never been carried into any considerable use.

In the thirteenth volume of the "Annales de Chymie," M. Berthollet gives an account of certain ideas which had occurred to him, respecting the defects of all the means used for dyeing with Prussian blue, and of some experiments made at his desire by Mr. Vidmer, of the celebrated calico printing establishment at Jouy, for correcting these defects. It was found by these experiments, that pieces of cotton, impregnated with the acetate of iron, or iron liquor, notwithstanding all possible endeavours to apply it equally, took up the colour of Prussian blue (first dissolved by potash, and then mixed with either sulphuric or muriatic

acid) so very unequally, as to leave no hope of success in this way. M. Berthollet accounts for this inequality of colour, by supposing, that one part or particle of iron is sufficient for six of the Prussian colour; and that, therefore, the slightest difference in the *distribution* of the particles of that metal in the mordant, becomes very sensible, when the Prussian colouring matter is afterwards superadded thereto.

Mr. Vidmer was particularly struck with the greens which were produced with the Prussian blue, upon patterns previously dyed olive in the usual way, by the iron liquor and weld, which greens greatly surpassed in beauty all those given by any other means.

M. Berthollet, by experiments which were afterwards made separately from Mr. Vidmer, discovered, that the solution of Prussian blue by lime water, (prussiate of lime) succeeded as well as that by potash, and that it required less care respecting the proportions: but he thinks, and with great reason, that the alkaline solution will have the advantage of being afforded cheaper, because when animal matters have been calcined with potash, nothing more will be necessary than to saturate the excess of alkali, by adding to it a little Prussian blue.

M. Berthollet's method was to dilute the prussiate of lime with three or four times as much water, or to dilute with a large quantity of water, a small one of the prussiate of potash,

and then to mix with it a little sulphuric acid;* and keeping the liquor at the heat of between twenty and thirty degrees of Reaumur's thermometer, to immerse the cotton, linen, or silk, therein, (having first soaked it in warm water) and turn it over a winch, &c. as usual, in order that the colour might be equally applied. The dye was found to take sufficiently in a few minutes, and then the stuffs were taken out and washed in cold water. He found the sulphuric acid preferable to the muriatic for this purpose.

Cotton and silk previously dyed grey or brown with galls, or other nigrescent vegetable colouring matters, applied to a ferruginous basis, acquired, by the process just mentioned, a blue colour, proportioned to the depth of the former brown or grey; and those which had been previously dyed olive, by the application of weld, or other adjective vegetable yellows, took also a beautiful green, proportionate to such olive colour. He says nothing of the effects of this method of dyeing on wool, having made scarce any trials therewith.

* The use of sulphuric acid will be readily understood, by recollecting that alkalies decompose Prussian blue by their greater affinity for its colouring matter than that of the iron, and that this last cannot, therefore, decompose the prussiate of potash, unless its affinity for the iron is assisted by that of an acid for the potash in the way of a double elective attraction.

Cotton and silk dyed black by the ordinary means, were found, by superadding a blue in M. Berthollet's method, to become more perfectly black, as well where the original colour had faded, as where it had been but imperfectly produced at first. He cautions against using too much acid, as well as against making the dyeing liquor too hot, and keeping the stuffs too long therein, especially the silk, which would thereby lose some of its lustre and softness.

One great defect, however, attending this method of dyeing, especially upon cotton, is, that the stuffs, to which the Prussian blue has been applied, will not bear washing, because, though the colour resists air extremely well, the alkali contained in soap readily dissolves and separates the Prussian colouring matter. As a remedy for this defect, M. Berthollet recommends washing the cottons, dyed by this process, with bran and water, instead of soap, which, he says, will likewise have the advantage of preserving the other colours of printed cottons, or rather of not injuring them, as washing with soap generally does in some degree.

Among the effects mentioned by M. Berthollet, that which I thought the most surprising was, the change of what he (improperly) calls an *olive* colour, *produced by weld and iron liquor*, to a very beautiful green, by the application of Prussian blue in the way before described. The *green*.

in this instance, manifestly could not be produced without a mixture of *yellow* with the blue; and weld, the only colouring substance from which it could, in this case, be obtained, never would afford any such colour without the aluminous, or some other basis, very different from iron. I determined, therefore, as soon as possible, to ascertain the truth respecting this point; and to do it, I took a large piece of cotton, which had been printed in parallel longitudinal stripes, (extending from end to end) first with a mixture of iron liquor and galls, next, with iron liquor only, then with a mixture of iron liquor and the aluminous mordant, (acetite of alumine,) and lastly, with the aluminous mordant only; then followed a white stripe, to which nothing had been applied, and these stripes were alternately repeated, so as to cover the piece. This I dyed in the usual way, with a decoction of quercitron bark, by which the first stripe became black, the second of a dark drab colour, the third of an olive, and the fourth yellow. I then took a solution of potash, fully saturated with the Prussian colouring matter, and poured some of it into a large vessel nearly filled with moderately warm water, and added to it a large proportion of oil of vitriol, (sulphuric acid) which, from its weight, sunk to the bottom. I took care, however, by stirring, to mix it thoroughly with the liquor, which be-

came uniformly blue, and had a sour taste. I then tore off a transverse strip of the dyed cotton, of the whole breadth of the piece, and immersed it, for a single minute only, in the liquor; when, on taking it out, I found that every particle of the colouring matter of the galls and quercitron bark had been discharged, and *replaced* by the Prussian colouring matter, upon the stripes where an iron basis had been at first applied; nearly according to the quantum of that basis. The first stripe, therefore, instead of being black, was of a very full, deep, strong, blue colour; the second was sufficiently full, though very sensibly weaker; and the third was still weaker; the fourth, to which the aluminous basis only had been applied, was of a very pale bluish colour, almost as slight as the fifth, which had not been impregnated with any basis or mordant. To diminish the excess of sulphuric acid in the liquor, as well as to replenish it with colouring matter, I added thereto a farther portion of prussiate of potash, which being properly mixed, I immersed another strip, torn from the same piece of cotton, and taking it out also, after a single minute, I found that, in this instance, the excess of sulphuric acid had not been so great as to discharge the colouring matter of the galls, though it had totally discharged that of the quercitron bark. I had, therefore, instead of a very

dark blue on the first stripe, a very full black, greatly superior to the former black from galls and iron, it having become much more intense by an additional body of blue colour. All the other stripes were very similar to those of the preceding trial. I then perfectly neutralized the excess of acid in the dyeing liquor, by adding to it a sufficient quantity of prussiate of potash; and a third strip of the same cotton being put into it for the same space of time, I found that none of the colouring matter of the quercitron bark was discharged in those parts or stripes where it had been united to the aluminous basis, though it had been every where decomposed and separated from the ferruginous, and its place supplied by the colouring matter of the Prussian blue. I had, therefore, on the second stripe, a blue colour, instead of the drab which the quercitron bark had produced with the iron liquor; and on the third stripe, instead of an olive, I had a very beautiful green, composed partly of the yellow from the quercitron bark and the aluminous basis, and partly of a fine blue, which the Prussian colouring matter had produced on the same stripe, by uniting with the ferruginous particles of the iron liquor, which had been previously mixed with the acetite of alumine, and applied as a mordant upon that stripe. The yellow upon the fourth stripe re-

mained in full perfection; and the fifth stripe was perfectly white, having been quite freed from a slight discolouration which the quercitron bark had produced on it in the dyeing vessel. By this, and many similar experiments, made some of them with weld, instead of quercitron bark, I clearly perceived that M. Berthollet must have been mistaken, when he supposed that the olives, which were changed into beautiful greens in the manner before mentioned, had been given by the weld and iron liquor *only*, because no such effect can be produced, either from that or any other adjective vegetable colouring matter, without the aid of alumine, or of oxide of tin, to produce a yellow, whilst the ferruginous basis, by attracting the Prussian colour, produces a blue, the other component part of the green.* I ascertained this fact more completely, by extending my experiments to woollen cloth, of which M. Berthollet says nothing in this respect. I be-

* M. Berthollet has since acknowledged his mistake, with becoming candour and promptitude; he says, (tom. ii. p. 319 of the last edition of his Elements, &c.) "Dans cette operation le fer se combine avec l'acide Prussic et forme du *bleu*, pendant que l'alumine fait du *jaune* avec la substance colorante; et *Bancroft a raison*, de combattre l'explication qu'on aurait donne de cette production de vert, dans laquelle on ne fesait point entrer le concours de l'alumine." And he then refers to his Memoir, Ann. de Chimie, tom. xiii.

gan by dyeing pieces of white broad cloth, some with weld and sulphate of iron, others with quercitron bark and the same sulphate, which, in both cases, produced nearly similar drab colours; and the pieces being so dyed, I immersed them in different portions of diluted prussiate of potash, neutralized with sulphuric acid, a little more than blood-warm, in which they all, after ten or fifteen minutes, became blue; the Prussian colouring matter having decomposed and separated that of the weld and quercitron bark, which, by suitable experiments, I afterwards found to be contained in the several liquors, where the Prussian colouring matter had before been suspended.* If, instead of dyeing the cloth with weld or quercitron bark, and sulphate of iron only, I used alum along with the latter, an olive was produced; and this, being soaked, as before mentioned, in warm diluted prussiate of potash, (neutralized with sulphuric acid) it produced a beautiful green; the alum and quercitron bark,

* This fact affords a remarkable *instance* and *illustration* of the *elective attractions*, subsisting between adjective colouring matters and the metallic oxides, alumina, &c. as we see that, in consequence of these attractions, the *colourable* prussiate was able to separate the colouring matters of weld and quercitron bark, when previously combined with their bases, and *fix itself in their stead.*

or weld, furnishing a sufficient quantity of yellow, for that purpose, and the Prussian blue, by its superior brightness, giving the green an increased lustre. In all these, and many other experiments, I found that though the Prussian colour in this way readily decomposed, and separated most of the adjective colours, united to a ferruginous basis, (for which it has a stronger attraction) it had not any attraction for the aluminous basis sufficiently strong to separate the colouring matters combined therewith: and hence, in all cases where a portion of alumine had been united with iron, to form the basis or mordant, and an olive colour had been thus produced by weld, or quercitron bark, either upon cottons, silk, or wool, a green invariably resulted, from an application of the Prussian alkali with sulphuric acid, unless where this acid was made to predominate so greatly as to decompose, even that part of the vegetable colouring matter which adhered to the aluminous part of the basis.

By reflecting upon these facts, I was led to a method of applying the Prussian blue for dyeing upon woollen, silk, and cotton, which seems to me capable of obviating the difficulty hitherto attending its use for these purposes. I have already mentioned M. Berthollet's opinion, that the inequality of colour to which the dyeing with Prussian blue is liable, arises from

the difficulty of applying the ferruginous particles alone equally to all the fibres of the cloth; though this may be easily done, when the particles of the iron are combined with those of different adjective vegetable colours; I therefore boiled up what I conceived to be suitable proportions of sulphate of iron with quercitron bark, fustic, and logwood, separately, and then dyed a piece of woollen cloth in each of these mixtures, by boiling it therein for ten or fifteen minutes; I chose these vegetable dyeing drugs, without any regard to their particular colours, because they are the cheapest, and because they do not contain any mixture of that particular substantive colouring matter found in galls, sumach, &c. which the Prussian colour would be less capable of decomposing and discharging. The pieces so dyed appeared to have imbibed the vegetable colouring matters equally, and as far as I could judge, the ferruginous basis also; and being afterwards immersed in warm diluted prussiate of potash, neutralized by sulphuric acid, they became *beautifully blue*; and though there were some little inequalities in the colour of one of the pieces, I ascribed it rather to my own want of attention to the proper stirring and management of the dyeing liquor, and of the cloth, than to any unavoidable difficulty in giving evenness to the dye. I found also, by subsequent experiments, that some nicety was

required to proportion the quantity of the oxide of iron (applied conjointly with the vegetable colouring matters) to the depth of blue colour intended to be dyed upon the cloth; for where an excess of the former was first applied, beyond the portion required to saturate the Prussian colourable matter, that excess gave the blue a greenish tinge. This, however, may be readily discharged, by passing the cloth through warm water, slightly soured by muriatic acid; though a few experiments would be sufficient to ascertain exactly the quantity of sulphate of iron necessary for producing any particular shade of blue in this way, upon any given quantity of cloth, and thereby obviate all difficulty on this point.* It is necessary always to apply the Prussian colouring matter in a moderate heat, otherwise it will be precipitated by the sulphuric acid, and rendered unfit for this purpose, unless dissolved again by potash, lime, &c.†

* I found afterwards, that the sulphate of iron would afford a sufficient basis for between sixty and an hundred times its weight of cloth according to the fulness of the blue intended to be dyed.

† Encouraged by the apparent success of these experiments, I have several times, since the former edition of this volume, renewed my attempts to render the Prussian blue available for dyeing broad-cloths, believing, from the *incomparable beauty of its colour*, and the constancy with which it resists all impres-

I shall offer something more respecting the use of Prussian blue for dyeing a most beautiful *green* upon woollen cloth, when I come to treat of the properties of quercitron bark.

To ascertain whether any affinity existed between the aluminous basis and the colouring matter of Prussian blue, I took a piece of cotton, which had been printed with the aluminous mordant, and cleansed as usual for topical dyeing, and immersed it in warm diluted prus-

sions from the sun and air, as well as of acids, that it might become an important acquisition, though unfit to withstand the action of soap; to which, indeed, broad-cloths are but rarely subjected. But though I have, in many instances, dyed pieces of cloth, of the size of those upon which my experiments are commonly made, (i. e. from six to twelve inches square) with a perfect evenness of colour, and with indescribable vivacity and lustre; I have, also, frequently failed to attain the requisite *equality* in the colour; and it has seemed to me that the extreme brightness of the blue, dyed in this way, has contributed to these failures, by rendering the *slightest inequalities strikingly perceptible.* I have now before me some of the pieces of cloth so dyed, and though the colour of several of them is intensely full, its lustre greatly surpasses every thing before seen in wool, and emulates even the *transparency* and brilliancy of the finest saphire, to such a degree that the eye, which has once seen the Prussian blue, so communicated, disdains afterwards to fix itself upon the common indigo blue. The seeming difficulty of giving the former of these colours with sufficient *evenness*, to a whole piece of cloth, has, indeed, hitherto restrained me from attempting to do it; but I am not without a strong hope of its being ultimately performed.

siate of potash; seeing, however, at the end of fifteen minutes, that it had acquired no colour, I put into the liquor a small proportion of a solution of iron by muriatic acid, which rendered it blue, and the cotton soon became of that colour pretty equally, without any manifest difference of colour in the places to which the aluminous mordant had been previously applied. Taking the cotton out of this dyeing liquor, I tore off a bit of it, and washed it with soap, which soon discharged all the colour, excepting where the cotton had been impregnated with alumine, and there it was considerably weakened, though enough remained to show that it had been attracted and rendered more fixed by the aluminous basis. Another bit of the same cotton was immersed in a solution of carbonate of ammonia, (mild volatile-alkali) which having a power of decomposing the Prussian blue, I supposed it would weaken, if not wholly discharge the colour. To my surprize, however, I found that it greatly augmented the blue, which before was rather pale, and gave it almost the appearance of what is called garter blue; an effect which will, perhaps, be the less surprising, if we consider, that volatile alkali, like the Prussian colouring matter, is an animal production, and that, excepting the carbone of the latter, both are composed of the same principles.

Another bit of the same cotton being put

into water, very slightly tinctured with a solution of copper by volatile alkali, the blue colour, in a very sudden and surprizing degree, augmented to an intensely deep garter blue, or violet, much exceeding that produced by the ammonia alone; and this being afterwards washed with soap, the colour of those parts where the aluminous mordant had been at first applied, was still better fixed than it had been on the like parts by the volatile alkali alone in the preceding trial.

Another piece of the same cotton being immersed in water, with which a very little muriate of copper had been previously mixed, soon became of a deeper blue, but without any of the purple or violet hue which had been produced in the two preceding instances.

This piece being afterwards washed with soap, I perceived that the colour where the aluminous mordant had been applied, was still much more firmly fixed than it had been by any other means. Indeed, after a severe washing, which completely discharged the colour every where else, the spots or parts impregnated with alumine retained a full strong blue, which the soap had, indeed, turned a little towards a violet colour; but, after being well rinced in clean water, it returned again to its proper complexion, and stood a long exposure to weather unaltered, and afterwards two or three severe

washings with soap, without much diminution of colour.* It must, however, be remembered, that if copper thus manifestly fixed the Prussian blue, it was only in those parts where the aluminous mordant had been at first applied; since the other parts of the cotton were washed white with as much facility as they were on the bit to which nothing had been applied after it became blue; so that, doubtless, both the alumine and copper together, greatly contribute to fix the colouring matter of Prussian blue. The copper, indeed, as we shall presently see, possesses a power of uniting therewith, and producing one of the most permanent of colours, even upon linen and cotton; a fact which, I believe, never was imagined by any one, until it very lately fell under my observation. From these proofs of the utility of an aluminous basis in fixing the Prussian blue, it would, I think, prove advantageous to prepare woollens by the usual boiling with alum, or alum and tartar, before they are dyed with copperas and quercitron bark, fustic, or log-

* In this and the other pieces, the blue upon the spots impregnated with alumine, after it had been weakened by washing, was rendered nearly as strong as ever, by dipping them into water, slightly soured with sulphuric acid, so as to decompose and neutralize the alkali which had been imbibed from the soap in washing; perhaps the acid also restored the oxygene which had been separated by the soap.

wood, for a Prussian blue. But in this case it would be necessary to mix a greater proportion of sulphuric acid in the prussiate of potash, or of lime, in order that an excess of acid may assist in discharging these vegetable colouring matters, otherwise, instead of a blue they would produce a green; or a black, where logwood had been employed with the sulphate of iron.

Having soaked pieces of silk and of cotton in the diluted prussiates of potash, soda, lime, and ammonia, or volatile alkali, separately, and afterwards dried them, I applied to each, by the pencil, a little of the solutions of all the metals and semi-metals in different acids, and also in alkalies, where they were soluble in the latter, in order to see the effects of all these several bases upon the Prussian colouring matter. I should tire the patience of my readers, were I particularly to describe the results of these different combinations, especially as no words could give adequate ideas of the great variety of shades and degrees of colour, and particularly of the blue produced by them, which varied extremely in fulness and brightness, as well as in its inclination towards the purple and violet on one hand, and green on the other; and, indeed, the diversities of blue only, (which was the colour produced by much the greatest number of metallic solu-

tions) would alone constitute a very pleasing variety of colour in the way of printing upon silk or cotton. There were, however, several other colours produced at the same time; *e. g.* the nitro-muriate of gold produced a very beautiful green, inclining a little to the yellow, which, by washing, changed somewhat to the olive, whilst the nitro-muriate of platina produced a green, inclining to the blue. The nitro-muriate of cobalt produced a grass green; the nitrate of mercury, a greenish yellow; and the nitrate of nickle, an olive brown.*

* As I have not abstained from correcting what has appeared to me erroneous, even though sanctioned by Newton in Optics, and Berthollet in Chemistry, it is my duty, with still greater promptitude, to detect, avow, and correct, my own errors, as far as I am able: and I therefore declare, that I was deceived when I supposed that the Prussian colourable matter had produced *blue* colours of different shades, in consequence of its combination with other metallic bases, besides that of iron. In the experiments just described, I had employed a prussiate of potash, in its mild state, without being sufficiently aware of the quantity of the oxide of iron, which it held in solution. Some of the metals also, and particularly the zinc, antimony, and manganese, contained iron, as is frequently the case; and some of the acids employed to dissolve them, contained it also, as frequently happens. From all these sources of error, of which I ought to have been more mindful, I ascribed, as Fabroni and many others had done, the property of giving a blue colour with Prussian colourable matter, (which, as far as I know, belongs only to iron) to metals which do not possess it.—Could I find *that property* in any *other* matter,

But the most remarkable, and, probably, the most useful, effect of these applications was, a very full, striking, lively colour, of which I cannot by words give my readers a perfect idea, because I do not remember to have ever before seen any colour exactly like it, and there is, I believe, no name in any language suited to it. It approaches nearest, however, to the highest and brightest colour of new copper, but inclines more to the red, and is accompanied with a kind of metallic shining lustre, which, in my eyes, appeared very agreeable. This colour (which I shall call the red prussiate of copper, until a better name be given to it) was produced by the different solutions of copper in the sulphuric, the nitric, the muriatic, and the acetous, acids, separately; and particularly well by that in volatile alkali. But the most remarkable circumstance attending the production of this *new* colour, was its extraordinary permanency, which was such, that though all the alkalies decompose the Prussian colourable matter when combined with iron, they have no effect upon its combination with copper; and the stability of the new colour is such, that

should eagerly recur to, and make trials of it, in the hope of being thereby enabled to communicate and fix the blue, under consideration, upon broad-cloth, &c. with greater evenness than has yet been found practicable, with the basis of iron.

neither acids,* nor washings with soap, however numerous, nor exposure to weather for the longest space of time, seem capable, in the least degree, of diminishing either its body or its lustre; and, therefore, I cannot help thinking, that it may prove highly useful, and more especially for calico printing, by way of *topical* application upon cottons, and, perhaps, in dyeing cotton-yarn for stripes of muslins, borders of handkerchiefs, &c. I have not experienced the same effect by applying a *direct* mixture of the Prussian colouring matter with a solution of copper, not even when I put the prussiate of ammonia into a solution of copper by ammonia, (which I thought most likely to answer); but have always found it necessary, either to apply

* I have since found, that by twenty-four hours immersion in the oxymuriatic acid, this colour was nearly decomposed; the Prussian colour being mostly separated, and the oxide of copper made green. But this fact affords no reason to doubt of its permanency for all the useful purposes in question. I found also, that a nitrate of silver, which contained a little intermixture of copper, being dropped upon cotton, stained or impregnated with the red oxide of copper, changed it to a beautiful greenish yellow; and that a nitro-muriate of gold, applied to cotton so stained, changed it to an orange. This, and the former pieces of cotton being dried, and afterwards washed with soap, that to which the nitro-muriate of gold had been applied, assumed a deep violet, and very fast colour; and that with the nitrate of silver, became green, probably in consequence of the copper, by which the silver had been alloyed, and that contained in the red prussiate of copper.

the Prussian colouring matter (dissolved by potash, soda, ammonia, or lime) *first* to the linen, cotton, or silk, and after suffering it to dry, to apply some one of the before-mentioned solutions of copper; or else to apply the metallic solution first, and then the prussiate; but in this last method, I have not found any solution of copper answer so well, unless it be that by ammonia, or volatile alkali.

Some years after the publication of my discovery of the red prussiate of copper, it engaged the attention of M. Proust, who satisfied himself, as I have since done, that to produce this red colour, it is necessary to impregnate the colourable Prussian matter, or a prussiate of potash, or lime, or ammonia, with that portion of *black* oxide of iron, which has been already mentioned, as necessary to enable the *red* oxide to become *blue*—and that a simple prussiate, destitute of the black oxide, though it unites with the oxides of copper, will only produce a yellowish brown colour; and I think, from my own experiments, that the colour in question is made to approach nearer to the *blood-red* by a little increase of the proportion of black oxide, beyond what would strictly be necessary to produce a Prussian blue with the red oxide of iron.*

* About the year 1802, the Journals of the Royal Institution, and several periodical works, announced that Mr. Hatchett

With cobalt the simple prussiate gives a cinnamon brown, less approaching to the blood red, than the prussiate of copper with the black oxide of iron: with an oxide of mercury this prussiate gives a *yellow*, sometimes inclining to the olive; and with gold, it gives a fine yellow. Having nothing more to offer concerning *animal* adjective colours, I shall next proceed to *vegetable*.

had *discovered* a very durable and useful *pigment* in the prussiate of copper, and without any mention of my name, though I had, ten years before, not only discovered this pigment, but what was of much greater difficulty and importance, the ways of fixing it permanently, by topical application, upon linen, cotton, silk, &c. and had published my discovery eight years before, in a volume, of which one thousand copies were in the hands of the public.—I hope I shall not be thought improperly anxious to do myself justice on this subject, when it is considered, that I have suffered ten years to elapse without any mention of it, even in private conversation.

PART III.

Of Vegetable adjective Colours.

CHAPTER I.

Of the Reseda luteola Lin. or Weld Plant, and some other Vegetable Yellows.

"Lutei video honorem antiquissimum, in nuptialibus flammeis totum concessum : et fortassis ideo non numerari inter principales, hoc est, communes maribus ac fœminis, quoniam societas principatum dedit."

C. Plinii secund. Hist. lib. xxi. 8.

By this quotation from Pliny, we learn, that the *yellow* dye, though highly esteemed from remote antiquity, was exclusively appropriated to the use of women, and that the *veil* which brides wore on the wedding day, was entirely of that colour.

The weld plant seems to have been employed to dye *yellow*, at least as early as the time when Virgil wrote his Eclogues ; for the *lutum* mentioned in his fourth, (line 44) was, doubtless, the reseda luteola, which grew wild in Italy, as it does now in various parts of Europe; though the cultivated plant, which is smallest, abounds most in colouring matter. There are some varieties of this plant ; and of these one was formerly put into my hands, which had been

imported from Hamburgh; of which the stalks were not a fourth part so tall, or so large, as those of the plants cultivated in England and France. I did not, however, discover any considerable superiority in the *quality* of its colouring matter, though in regard to *quantity* it yielded more than four times as much as an equal weight either of English or French weld. This smaller variety, according to my information, grows, and is used by the dyers, in several parts of Germany.

Weld requires the growth of nearly two summers before it comes to maturity, and the crop is besides liable to fail from so many causes, that it cannot be a desirable object of agriculture in Great Britain. Indeed, it will not come to maturity in the northern parts of this island, and the expence of transportation is so great, by reason of its bulk, that the calico printers of Lancashire, Carlisle, Glasgow, &c. could not have exercised their art, either so advantageously or so extensively as they have done, if my discovery of the properties and uses of the quercitron bark, (to be mentioned in the next chapter) had not come to their relief, and moreover afforded them other important benefits.

To give a full yellow colour to wool or silk, twice its weight of either English or French weld is deemed necessary; and from the extent of space which the stalks of the plant occupy,

(the roots being useless) it is necessary to extract the colour separately, previous to the dyeing operation; which, however, must take place soon after such extraction, as the decoction will otherwise speedily undergo a decomposition, sufficient to render it useless.

The old book translated from the Dutch, and printed, as before mentioned, in 1605, directs the employment of stale urine and wood ashes with water, to extract the colouring matter of this plant, which was afterwards to be fixed on linen by verdigrise instead of alum, though the latter appears to have been employed as the mordant for wool; and this practice seems to have subsisted ever since, with but little alteration.

Wool, or woollen cloths, are commonly prepared for the weld yellow, by boiling them the usual time with a fourth or fifth of their weight of alum, and a twentieth of their weight of tartar; which last is supposed to render the colour a little more delicate and lively; and the yellow may be farther improved by adding, either to the preparation, or the dyeing liquors, a small portion of the muriate, nitro-muriate, or murio-sulphate of tin.

Linen thread, or cotton yarn, are commonly prepared for the weld yellow, by copious impregnations with the aluminous basis, to which a little lime or chalk is sometimes added; a

little powdered verdigrise is also sometimes mixed in the *dyeing* or weld liquor.

Weld appears to contain a large portion of potash, neutralised chiefly by phosphoric and malic acids.

In topical dyeing, or calico printing, very little less than the heat of boiling water will suffice to fix the colouring matter of weld; and the parts wanted to be kept white, are then so much stained by it, and this stain is so difficult to remove, that, during the damp cloudy weather which generally prevails in winter, four or five weeks exposure on the grass will hardly prove sufficient for that purpose. This is a serious inconvenience which does not attend the use of the quercitron bark, and which has caused the latter to be generally employed by calico printers to almost the total exclusion of the former; though, it was their only resource for dyeing yellow, until the recent introduction of quercitron bark.

Weld also produces another bad effect when employed for topical dyeing upon linens or cottons, which have previously received madder colours; for in this case, the *weld yellow*, by a particular affinity, applies and fixes itself upon these colours so copiously as to change their appearance, and tarnish their lustre greatly; and this is another defect,

from which the bark is nearly, if not wholly, exempt.*

By the Act of the thirteenth of his present Majesty, ch. 77, the sum of 2000l. was granted to Dr. Richard Williams, as a reward for his invention of a fast green and yellow dye on cotton yarn and thread. This supposed fast dye was given with weld, by the help of a mordant; the composition of which (that foreigners might not enjoy the benefit of it) Dr. Williams was permitted to conceal, and to supply the cotton and thread dyers with the mordant at a certain price. I have, however, reason to believe, that it was either a solution of tin alone, or of tin and bismuth, which enabled the weld yellow, as it enables that of the quercitron bark, to bear the action of acids and of boiling soap-suds, though unable to bear the action of sun and air. This defect, however, was not readily discoverable by the method which Dr. Williams employed to obtain a favourable testimony from the dyers on this subject. His

* The opaque yellow, employed for paper hangings, is obtained by mixing clean white calcareous earth, with a solution of alum, sufficient in quantity to convert the former into a saturated sulphate of lime, which subsiding along with the alumine, forms a basis for the colour; and this basis is made yellow by applying to it a strong decoction of the tops and seeds of the weld plant, and it is afterwards dried and formed into cakes.

method was that of weaving the dyed yarn into pocket hankerchiefs, so as to produce yellow stripes or borders, and giving them to be worn in the pockets of those who were afterwards to attest the goodness of his dye; and as handkerchiefs inclosed in a pocket are not exposed to the sun and air, the defect in question was not perceived until some time after the reward had been paid for a supposed invention of no value, and of which, I believe, no use is now made.

Art. 2d. Rhus cotinus, Lin. or Venice sumach, improperly called *young* fustic, is a shrub growing principally in Italy and the South of France; whence the root, as well as the stem or trunk of the shrub, deprived of the bark, are brought and employed (after being chipped) for dyeing a full high yellow, approaching to the orange, upon wool or cloth, prepared either with alum or the nitro-muriate of tin. But the colour obtained by these means has been always deemed very fugitive. I find, however, that this defect, in regard to the last of these mordants, may, in a great degree, be obviated, by employing *tartar* along with the nitro-muriate of tin. Four pounds of the rhus cotinus chipped, afford no more colour than one pound of the quercitron bark. This appears to be the shrub mentioned by Pliny, (lib. xvi. cap. 8) as growing in the Appenines, and called *cotinus*.

Art. 3d. The rhus coriara; elm-leaved, or common sumach of Spain, Portugal, and other parts of Europe, as well as of North America, affords a yellow dye with the aluminous basis; but so pale that it is but little employed for the purpose of giving a yellow colour only; it, however, possesses another species of colouring matter, similar in most respects to that contained in galls, which renders it useful for drab and dove colours in calico-printing, and also capable of dyeing black with iron and the solutions of that metal: this species of colouring matter, and the application thereof, upon wool and cotton, will be treated of in their proper places. The principal uses of sumach with quercitron bark, in calico printing, will be noticed in the next chapter. Employed by itself in this way, it gives a troublesome stain to the white parts, which is obviated by using it with the quercitron bark, and it is diminished when used by itself, by employing only a very moderate heat, in which calico, printed with acetite of alumine and iron liquor, of different degrees of strength, will receive yellow, black, and grey colours, sufficiently lasting.

There are several other species of sumach, which grow spontaneously and abundantly within the United States of America, and produce colours similar to those of the rhus coriara; particularly the rhus glabrum, called scarlet sumach, from the colour of its acid berries

which are produced in clusters, and used by the aborigines of North America as *mordants* to fix the red colour of a species of gallium, with which they have long dyed their porcupine quills; also the rhus typhinum, called Virginian sumach, the rhus copallinum, or lentiscus-leaved sumach, &c.

The bark of the roots, stems, and woody branches of all these shrubs contains a large proportion of that species of colouring matter, which gives a black colour with iron, and which was erroneously supposed to distinguish and belong exclusively to what have been called astringent vegetables: but for *dyeing yellow*, the colouring matter of the leaves and young green shoots is greatly preferred; and in the countries where sumach is cultivated for the use of dyers, the stems are never allowed to become woody, the young shoots being cut down every summer, and ground up with the leaves.

I formerly endeavoured to concentrate the colouring matter of sumach (with the tannin which accompanies it) by reducing it to the form of a dry extract, for the use of dyers and tanners, but I found it strongly disposed to deliquate or attract moisture; probably, from the *malic* acid which seems to abound therein.

In regard to the colouring matter of the *wood* of the large stems of the old full-grown shrubs, it seems, in all the species, to resemble that of the rhus cotinus, (Venice sumach or

fustic) mentioned in the preceding article, and in my experiments has produced exactly similar effects.

Pliny mentions (lib. xxiv. c. 11.) the leaves of sumach, which he calls rhus erythros, as being employed instead of pomegranate rinds to prepare skins, (leather) and the berries as being used instead of salt, to preserve and season, or give relish to meat—and the savages of North America formerly employed the berries of their scarlet sumach for the same purposes.

Art. 4th. Morus tinctoria, Lin.* called improperly *old fustic* by the English, and bois jaune by the French, is a large tree growing naturally in Jamaica, Porto Rico, Tobago, and almost all the other West India islands; its wood is of the colour of sulphur, and has, within two centuries, been brought into general use as a dyeing drug, though the yellow colour, which it affords with an aluminous basis, is neither high nor bright; it has, however, the advantage of being durable, and of not being thrown down or made latent by acids so much as the weld and quercitron yellows; and for this reason it is now very com-

* The fruit of this tree in size and shape resembles the white mulberry; and like other mulberries, has its *acini* both within and without the pulp, which are of a greenish colour. Whilst unripe, the fruit is milkey; but at maturity it is lusciously sweet Birds feed on the fruit, and by dispersing, plant the seeds.

monly employed (chipped or ground) in dyeing Saxon greens upon cloth, with the sulphate of indigo, as mentioned at pages 337 and 338 of vol. i.; the muddiness of its yellow being of but little detriment to the full dark greens most frequently dyed with it in this way.

It is also very much employed for dyeing drab colours upon cloth, and especially on cotton-velvets, fustians, &c. with an iron basis, and olives with a mixture of this and of the aluminous basis, as will be mentioned in the succeeding chapter, where so much will be found respecting the means and modes of employing the quercitron bark to produce similar colours, which it does with equal advantage, that I shall add but little more upon this subject. Four pounds of this wood chipped, yield about as much colouring matter as one pound of the quercitron bark, and allowing for this difference of quantity, it may be employed for general dyeing with the several mordants or bases proposed for the bark; remembering always that the yellow colour which it affords, can never be made to acquire any thing like an equal degree of clearness and brightness with that of the bark or of the weld; and for this, with some other reasons, it is not likely to be ever employed in calico printing.*

* Since this was first printed, M. Chaptal has found means, which will be mentioned presently, to obviate the muddiness of this yellow, in a great degree.

I am not yet able to ascertain whence the word fustic was derived to our language. Venice sumach appears to have been long distinguished in France by the name of *fustet*, and I suspect that our dyers with the wood, introduced the name, and changed it to *fustic*; such changes having frequently happened in other cases. The morus tinctoria being afterwards brought from America, and also employed for dyeing yellow, and being destitute of a name, appears to have likewise acquired that of fustic; and a confusion having arisen by thus giving the same name to two different species of wood, a distinction was improperly created by calling that of the Venice sumach, *young* fustic, (as being manifestly the wood of a small shrub,) and that of the morus tinctoria, (which is always imported in the form of large logs or blocks) *old* fustic. At what time these epithets were first applied, to create this distinction, I have not discovered; but they must have been in general use, at least 130 years ago; because Sir William Petty, in an account "of the Common Practices of Dyeing," which he gave to the Royal Society when first instituted, mentions Venice sumach under the name of "*young* fustic," and the morus tinctoria under that of "*old*," as being their common and appropriated names. In this way, however, many persons have been misled so far as to conclude, that two very distinct dyeing drugs (the one a

small *European shrub* of the sumach kind, and the other a large *American tree* of the mulberry kind) were the same, or differing from each other only in *point of age*. The French have, indeed, avoided this source of error, by leaving the Venice sumach to bear exclusively the name of *fustet*, and giving that of bois jaune, or yellow wood, to the morus tinctoria; and, perhaps, it might be well for us, even now, to call the latter *yellow wood*, or *dyers' mulberry*, in order to avoid the error in question.

This wood, like some others, contains both a resinous and an extractive colouring matter, and both appear to be mixed with a portion of *tannin*, or the tanning principle, which tarnishes the yellow of the colouring matters, and M. Chaptal has lately found (See Memes. de l'Institut, tom. i.) that glue, when added to a decoction of this wood, precipitated the tannin, and thereby enabled the superincumbent liquors to dye yellows almost as bright as those of weld and quercitron bark.

The wood known in England by the name of green ebony, possesses a species of yellow colouring matter very similar to that of the morus tinctoria in dyeing, and is sometimes employed in its stead.

Art. 5th. The unripe berries of the rhamnus infectorius of Linnæus, are called French

berries, and chiefly employed for preparing a lively, but very fugitive, yellow for topical application in calico printing.* Cotton printed with the aluminous mordant, and dyed with these berries, instead of weld or quercitron bark, receives a full bright yellow; but in this and every other way it fades so speedily, that the use of it should not be tolerated, whilst there are other means of giving much more durable yellows. There is a particular species of the rhamnus, growing in Candia, and other parts of the Levant, yielding berries larger than those brought from the South of France; they are distinguished by the name of Turkey berries, and preferred to the French, though the colours of both are fugitive. Great quantities of them are exported from Salonica, to which they are brought from Thessaly and Albania.

Art. 6th. Saw-wort, serratula tinctoria, Lin. affords a good substitute for weld in dyeing upon

* M. Duhamel asserts, that the French berries, or grains d'Avignon, are produced by the rhamnus infectorius, which (as well as the rhamnus saxatilis and other species) certainly produces berries giving a yellow colour. But professor Martyn, in his Edition of Miller's Gardeners' Dictionary, contends that these berries are the fruit of the narrow-leaved alaternus, a shrub which grows abundantly in the South of France; and he asserts, that having collected its berries, and shown them to several dealers in the article, they offered to buy them as French berries.

the aluminous basis, with which it communicates a bright lemon yellow of considerable durability. The common preparation with alum and tartar, is to be employed for this yellow upon wool and cloth; or if a brighter colour be wanted, the preparation may be given with nitro-muriate of tin, (dyers spirit,) and half as much tartar.

For giving a very inferior yellow upon coarser woollens, the dyers broom (genista tinctoria, Lin.) is sometimes employed, with the common preparation of alum and tartar.

Art. 7th. All the five species of erica, or heath, growing on this island, are, I believe, capable of affording yellows much like those obtained from the dyers' broom—their colours may, indeed, be raised and brightened by the solutions of tin; but when this has been done, they have, with me, always proved fugitive. This I have also found to be the case of the yellow, dyed with the bark and shoots of the Lombardy poplar, (populus dilata, or pyramidalis,) recommended by Mons. d'Ambourney, though they are poor in colouring matter, seven pounds weight of them being required to dye a single pound of wool.

Art. 8th. The American golden rod, (solidago canadensis, Lin.) affords good yellows to wool, silk, and cotton, upon the aluminous basis. Hellot seems to have been the first who attempted, though without success, to introduce this plant into general use as a yellow dyeing drug; and

Messrs. Gaad and Succow have since made the like attempts with no better success; though I can affirm, from the results of many trials, that it would prove a very advantageous substitute for the weld in calico printing; the colour which it affords in this way, to parts printed with the aluminous mordant, being in no respect inferior, and the stain or discolouration produced upon the unprinted parts, being much less and much more easily discharged than that of weld. The plant (golden rod) is also more rich in colour, and capable of being raised with great ease. It grows naturally in abundance, almost every where, between Carolina and Hudson's Bay.

Kalm says, that the three-leaved hellebore, (helleborus trifolius,) called tissavoyanne jaune, by the French in Canada, is there used by the Indians in giving a fine yellow colour to several kinds of work, which they make of prepared skins; and that the French having learned this from them, dye wool and other things yellow with this plant.

Besides these, there are many other vegetables capable of affording adjective yellow colours, both with the aluminous basis and that of tin, particularly the seeds of purple trefoil, lucerne, and fenugreek, the flowers of French marygold, the chamomile, (anthemis tinctoria,) the ash, (fraxinus excelsor,) the fumitory, (fumaria

officinalis,) the leaves of the sweet willow (salix pentandria,) the verbascum thapsus, Lin. the agrimonia eupatoria, or common agrimony, the bidens tripartita, or trifid water hemp agrimony, the leaves and branches of the lemon tree (citrus,) and others, which need not be named, because they are not likely to be ever considerably employed. Besides these, Loureiro mentions the fibraurea tinctorea, a climbing shrub, and pterocarpus flavus, a large tree, both growing in the woods of China and Cochinchina, and affording yellow dyes; as does the fruit of the gardenia florida. He also mentions the roots of the morinda umbellata, as being employed in Cochinchina to dye cloth of a permanent saffron colour.

Ventenat has described a species of tagetes (papposa) growing on the banks of the Mississipi, and affording, as he says, a durable yellow dye.

The Elder Michaux observed in the western division of the Tenesee country, (North America) a species of sophora, nearly related to the sophora japonica, employed by the Chinese as a yellow dye, and conceived that it might become an object of great importance. The younger Michaux adopting this idea, sent a parcel of the wood to M. Chaptal, then Minister of the Interior in France, and he soon after gave me a sample of it, (when I met him in South Carolina in the year 1802,) which, though it had

been purposely made very small, enabled me to satisfy myself that it could never maintain any sort of competition with the quercitron bark.

Professor Woodhouse, of Philadelphia, mentions the hydrastis canadensis as imparting to silk "a rich and superb yellow colour," and he afterwards gives an account of many experiments which he had made with the xanthoriza tinctoria, but concludes it by stating as his opinion, that, "that truly valuable dyeing drug, the *quercitron* bark, will always supersede the xanthoriza, *and every other native* (i. e. American) yellow dye."

There is, indeed, so much difficulty in always producing the exact shades of colour which dyers are required to imitate, that the use of *various* materials for obtaining *similar* effects must always prove highly inconvenient. A few drugs occupying but little space, rich in colouring matters, and capable of being always obtained, as well as extensively applied, by saddening and otherwise diversifying their respective colours, are to the dyers most needful and useful: by being constantly occupied with a few such drugs, they acquire that degree of dexterity and certainty in the use and management of them, which alone can prevent disappointment in the nice operations of this art.—Such a drug is the quercitron bark, which will be the principal subject of my next chapter.

CHAP. II.

Of the Properties and Uses of Quercitron Bark.

"Il n'y a pas de proprieté plus respectable que les decovertes de "l'industrie."

BERTHOLLET, *Ann. de Chymie, tome* vi.

THE *Quercitron* bark is produced by the quercus nigra of Linnæus,* which might now be more properly denominated quercus tinctoria;†

* The name of *quercitron* was given by me to this species of oak, and derived from the Latin words, quercus *citrina*, which I thought more suitable than the denomination of Linnæus: and being so given, the name was adopted and sanctioned by an Act of Parliament, of the 33d year of his present Majesty, (entitled an act for allowing the importation of quercitron, or black oak bark, &c.) and it has become the prevalent name in France, Germany, and other parts of Europe.

† Since this was first printed in 1794, the elder Michaux, has adopted the name of quercus tinctoria, in his "Histoire des *Chenes* de l'Amerique, ou description et *figures* de toutes les espéces et variétés de chenesde l'Amerique septentrionale, &c. par André Michaux, Membre Associé de l'Institut National de France, &c." Paris, 1801, folio. In this work the author describes 20 species of American oaks, of which his 13th is that which affords the *quercitron* bark. His character of it, is "Quercus foliis petiolatis, subtus pubescentibus, lato-obovalibus, leviter, et subrotunde lobatis; basi obtusis: cupula subscutellata, aut turbinata; glande depresso-globosa aut ovata."

Of this species he makes two varieties.

1st. "*Chene Quercitron*, a feuilles angulensis,—great black

and is one of the objects of a discovery, of which the use and application for dyeing, calico-printing, &c. are exclusively vested in me, for a term of years, by an Act of Parliament passed in the 25th year of his present Majesty's reign.*

oak—Champlain black oak." He represents this tree as growing from lake Champlain to Georgia, always in a good soil, and at some distance from the sea; and as rising from 60 to 80 feet high, with a trunk from 6 to 10 feet in diameter, in Georgia; but smaller northward. This is the variety which I have endeavoured *exclusively* to introduce as a *dye*. His second variety is "Chene quercitron a feuilles sineueuses." Having sinuated leaves, and growing chiefly in the *low* parts of Georgia and South Carolina. The yellow colouring matter of this species is combined with another, which gives a brownish tinge, or tint, called *fauve* by the French; a circumstance in which it agrees with what I suppose to be the quercus aquatica, or *water* oak, of Catesby.

* About four years after *this* paragraph was written and published, the *term* of the *act* in my favour expired; but as I had, during its continuance, exercised my rights more liberally and beneficially for the public, than providently towards myself and family, and as I had, moreover, been frustrated of a great part of my just profits, by various infringements of this act, and by obstructions and losses resulting from the war, a bill was introduced, and *passed* by the House of Commons, in the 39th of his present Majesty "*for enlarging, for the term of seven years, and continuing the powers*" of the *former act* in my favour: This bill (or act of the House of Commons) was, however, lost in the House of Lords, by a *postponement* of the second reading, in consequence of the opposition of a great number of persons in the Northern parts of the Kingdom, who had greatly profited by my discovery, and of whom some had grown rich

The bark of this tree appears to consist of three parts or coats.

and powerful in a considerable degree from it. And thus, without being heard by my counsel, who were in attendance, or being allowed to repel, as I was prepared to do by adequate testimony, the groundless allegations of my opponents, and though more than three-fourths of the Calico Printers, and consumers of the quercitron bark, in *the Southern parts* of the kingdom, had petitioned the House of Lords *for the prolongation* in question, I was left with *very little* remuneration for the labours of a great part of my life; excepting the consciousness of having done good to many persons, who appeared to be neither sensible of, nor grateful for it. I have, however, long since forgiven my opponents. Most of them had been made to believe that my profits were five times greater, than they were in truth; and that their own interests would be greatly promoted by this termination of my rights; though many of them had previously certified under their hands, that the advantages resulting from my discovery had been greatly increased by the beneficial manner in which these my rights were exercised: and this fact was strongly asserted by the petition, just mentioned in my favour, in which the Petitioners declare that they "have never experienced any inconvenience from the exercise of any of the rights vested in Dr. Bancroft, by the act formerly passed in his favour; but, on the contrary, are convinced that they have been invariably exercised upon a plan of all others the most conducive to the public good, and at the same time with such liberality, that the inconveniencies usually attending monopolies have been thereby avoided." "That although dyeing-woods and drugs from America have generally risen since the war began, and some of them to more than five times their former prices; and although, from the great abundance of colouring matter in the quercitron bark, and its useful properties, joined

1st. The epidermis, or external coat, through which the several excretions of the tree are trans-

to a great addition to the cost thereof, and more especially to the freight and charges attending its importation during the last six years, Dr. Bancroft might have been entitled and enabled to advance the price of the said bark, in a proportion at least, equal to that of other dyeing drugs, or woods from America, yet he has invariably supplied your Petitioners, and other consumers thereof, at the *very lowest price,* to which it had been reduced by him before the present war, and by so doing, has relinquished the fair profits of his invention, to a greater amount than any profit which he is likely to make, by supplying this bark for a farther term of seven years, at the low price intended to be fixed for the same, by the bill in question."

The Petitioners moreover declared themselves " fully persuaded, that it would be *safest and most advantageous* for themselves, and other consumers of the quercitron bark, to continue *secured* of sufficient supplies thereof, during a farther term of seven years, at the *low* price intended to be fixed for the same by the bill in question, and thereby exempted from those frequent variations and augmentations of price, which might otherwise be expected, so long, at least, as the war should continue, by the practices of those who, from time to time, might find means to engross the said bark."—That this persuasion had been well-founded, was soon proved by the event, for in less than twelve months this bark rose to three times the price at which it had been invariably supplied by me, and at which I should have been bound to supply it, for another term of seven years, if the bill had become a law; and it has on the average been at nearly double that price to the present time. —This is the *only instance,* I believe, in which an invention ever became more *costly,* after the expiration of a monopoly, granted to remunerate the inventor, than it was during the

mitted, which, in part at least, adhere to its outer surface, where they harden, and become almost *black*, by condensation, and probably by an absorption of oxygene; and hence the Linnæan denomination of *black* oak has originated; that great naturalist having had no knowledge of the properties of this bark in dyeing.

2d, The middle or cellular coat, in which the colouring matter principally resides; and,

3d, The interior or cortical part, consisting chiefly of lamina, formed by the re-union of different vessels, which become more hard and fibrous, as they are placed nearest to the woody part of the tree, and have, therefore, less room to contain the colouring matter.

The epidermis, or exterior blackish coat of this bark, affords a yellow colouring matter, which, however, is less pure, and more inclined to a brownish hue, than that of the other coats or parts; and it ought, therefore, to be separated by shaving. When this is done, and the remaining cellular and cortical parts are ground by mill-stones, they will separate partly into a light fine powder, and partly into stringy filaments or fibres, which last yield but about half as much colour as the powder, and, therefore, care should be always taken to employ both to-

continuance thereof, and it has *demonstrated,* most *incontrovertibly,* that my opponents were greatly *deceived, and that* I was greatly wronged.

gether, and as nearly as possible in their natural proportions, otherwise the quantity of colour produced may either greatly exceed or fall short of what is expected. The quercitron bark thus prepared and proportioned, will generally yield as much colour as eight or ten times its weight of the weld plant, (reseda luteola, Lin.) and as much as about four times its weight of the chipped old fustic (morus tinctoria, Lin.): but the colouring matter of the bark, in its nature and properties, most clearly resembles that of the weld plant; with this advantage, however, that it is capable *alone* of producing more cheaply, all, or very nearly all, the effects of every other yellow dyeing drug; and, moreover, some effects which are not attainable by any other means yet known.

The quercitron colouring matter may be readily extracted by water, even when it is only blood warm; but if the infusion be strained and left at rest, a small portion of resinous matter will separate and subside in the form of a whitish powder, capable of giving colours similar to those of the non-subsiding parts or particles. The clear infusion being evaporated, will afford an extract which, when completely dried, has, I think, commonly weighed as much as about one-twelfth of the bark from which it was obtained, and yields nearly as much colour as the whole of the bark. But it has been found very difficult

to make this extract in any large quantity, so as to render it capable of giving colours equal in beauty to those obtained *directly* from the bark itself; because, if the evaporation be rapidly performed, with a considerable degree of heat, the colour always becomes tarnished, probably by a combination of oxygene, producing effects similar or approaching to those of a slight combustion; and if the evaporation be conducted *slowly*, the colouring matter suffers greatly by another change, like that to which the decoction of weld is always liable, and by which the latter usually spoils by keeping, even in less than 24 hours.

There are several varieties of the Quercus nigra, all containing a portion at least of the same species of colouring matter; but some of them, (particularly the quercus nigra digitata,* and

* This seems to be Michaux's 2d variety, or "Chene quercitron feuilles sineueuses;" of which a cargo was imported from South Carolina about the year 1785, by one of those who, about that time, infringed my rights; and its bad effects threw some discredit upon the true quercitron bark, by its being mistaken for the latter.

The oaks of America are, however, so numerous, and so apt to vary the forms of their leaves *by age*, that it is often difficult to distinguish one from the other, at least by their leaves. The younger Michaux, after stating the quercitron oak to be very common in the Northern States, and Westward of the Alleghany mountains, though but rare in the lower parts of North and South Carolina, and Georgia, says, that the leaves of its lower branches affect a form different from the upper; "Celles ci

the quercus nigra trifida, both of Marshal,) besides the yellow, contain a species of the *fauve*, or fawn colour, which tarnishes the yellow, and in calico-printing, occasions another

(he observes,) sont plus profondement échancrees," and he adds, that the figure of this oak in the " *Histories des Chenes*," &c. represents only the leaves of the *lower* branches, and of the *young* trees. He mentions, however, as a means of distinguishing this oak, that in all the other species " le petiole, les nervures, et les feuilles elles memes, sont d'un *vert* plus ou moins foncé," and that towards autumn this colour darkens, and becomes more or less red. But that the *same parts* in the " quercitron, sont dans le printems *jaunatres*, et comme pulverulentes," and that this *yellow* colour becomes the more marked as the winter approaches. He also mentions another peculiarity, which will point out the oak in question, when the leaves are fallen in winter; and this is the *bitter taste* of its bark, and the *yellow* colour which it gives to the saliva when chewed. He adds, indeed, (what he mentioned to me in 1802) that he thought he had observed nearly similar properties in the bark of the quercus cinerea; but this last species may always be known from the other, because it grows only in the most dry arid spots of the Southern States, with lanceolated leaves, and seldom attains more than 18 feet in height, with 4 inches in diameter, whilst the quercus tinctoria, or quercitron oak, often rises 80 feet above the ground, and its leaves have each *several lobes*. See Voyage a L'Ouest des Monts Alleghany, &c. par F. A. Michaux, M. D., &c.

By order of the French government, M. Michaux sent to France large quantities of the acorns of the quercitron oak, from which great numbers of plants have been produced in the nursery of *Trianon*, and in other places, with a view to the *bark* hereafter.

bad effect, that of staining those parts of the cotton or linen intended to be kept white, so as to make the bleaching of them afterwards very difficult. The barks of these last mentioned varieties have sometimes been mixed with that of the better sort, and in considerable quantities, (through the ignorance or the inattention of labourers employed in the collection,) so as to bring discredit upon this new and truly valuable dyeing drug : but there is reason to hope, that such improper mixtures will hereafter be avoided, in consequence of the very particular instructions which have been given for that purpose.

The decoction of quercitron bark appears to be of a yellowish brown colour, which is darkened by alkalies, and rendered lighter by acids ; alum dissolved in it, separates but a small portion of the colouring matter, which subsides in the form of a deep yellow precipitate. Either the muriate, the nitro-muriate, or the murio-sulphate of tin, mixed with a decoction of the bark, produces an exceedingly beautiful lively yellow, and occasions a much more copious precipitation than the alum ; probably because the calx of tin is heavier, and unites with the colouring matter in a much larger proportion.

Sulphate of iron, dissolved by a decoction of this bark, produces a copious dark olive precipitate, and the clear supernatant liquor remains of a light olive green.

Sulphate of copper in the like decoction, oc-

casions a precipitation which is of a yellow inclining to the olive, and leaves the supernatant liquor of a yellowish green.

The effects of other bases and chemical agents upon the colouring matter of the bark, so far as they appear of any importance, will be discoverable from the following account of its various uses in dyeing and calico-printing.

Of the Application of Quercitron Bark for the Dyeing of Wool and Woollen Cloths, with an Aluminous Basis.

WOOL, and the cloths or stuffs made from it, ought, in all cases, to be scoured before they are dyed, in order to separate a kind of grease with which the fibres are naturally covered. This is usually done by immersing the wool or cloth for about a quarter of an hour in stale urine, diluted with three times as much water, and kept nearly of a scalding heat;* it is afterwards to be thoroughly rinced in clean water, and then dyed or impregnated with the proper mordants for dyeing, without any previous drying, that the colour may apply itself more equally.

Alumine, or the earth of alum, precipitated by clean potash, and repeatedly washed in pure water, being boiled with quercitron bark, readily united with its colouring matter, and pro-

* See more on this subject at p. 86 of Vol. I.

duced a yellow inclining very much to the golden, or, as it is called, the *yolkey* hue; and wool boiled in this mixture for the space of half an hour, took a brownish yellow which, however, seemed to have been but superficially applied, the earth of alum, in its undissolved state, not being able sufficiently to enter the pores of the wool, even when they are distended by boiling water.

The earth of alum, dissolved by the vegetable, the fossil, and the volatile, alkalies separately, as well in their mild as in their caustic states, was found to dye yellow colours of different shades, with the quercitron bark upon wool; but they were all inferior to those given by the same basis (alumine) when dissolved by acids.

The cheapest and most simple method of applying the quercitron colour upon wool, is that of boiling up the bark with its weight, or a third more than its weight, of sulphate of alumine, (common alum) in a suitable portion of water for about ten minutes, and then dyeing therein the wool or cloth previously scoured, as before mentioned, taking care to give the higher colours first, and the paler straw colours afterwards. In this way yellows not wanted to be very full or bright may be dyed very expeditiously and cheaply; and they may afterwards be considerably raised and enlivened, by passing the wool or cloth, unrinced, a few times through hot water,

into which a little clean powdered chalk has been previously stirred, in the proportion of about a pound or a pound and a half of chalk for each 100lb. weight of wool or cloth. The bark, when used in dyeing, (being first ground,) should always be tied up in a linen bag, of a loose open texture, and suspended in the dyeing liquor by a cord, with which it may be dragged occasionally backwards and forwards through it, to extract and spread the colouring matter more equally.

But when the bark and alum are boiled together and united in this way, the colour does not afterwards fix itself either so readily, or so copiously upon the wool or cloth, as when the aluminous basis has been first applied separately in the common mode of preparation; and, therefore, this simple and cheap method of applying the quercitron colour is only suited for straws and pale yellows, especially as there is reason to suspect, that the adjective colours of every kind are not so durable when died with an alumnious basis in this way, as when they are dyed upon a like basis previously conveyed into and fixed in the substance which is to be dyed.

As often, therefore, as any thing more than a pale yellow is intended to be given from the quercitron bark and the aluminous basis upon wool or cloth, the latter should be boiled in the common way, but *without either tartar or argol*, for the space of an hour, or an hour and a quar-

ter, with about one-sixth or one-eighth of its weight of alum, dissolved in a suitable quantity of water, and then, *without being rinced,* it should be put into a dyeing vessel, with clean hot water, and about as many pounds of powdered bark, (tied up in a bag,) as there were used of alum to prepare the wool or cloth, which is then to be turned, as usual, by the winch through the boiling liquor, until the colour appears to have taken sufficiently; and then about one pound of clean powdered chalk for every 100lb. of the wool or cloth, may be mixed with the dyeing liquor, and the operation continued eight or ten minutes longer, when the yellow will have become both higher and brighter by this addition of chalk.

The yellows given in this way from the quercitron bark are infinitely better, and considerably cheaper, than any which can be given from old fustic with an aluminous basis: indeed, they approach nearly to those given by weld with the common preparation of alum and tartar, and are in every respect as durable; though it must be confessed, that they have less of that lively greenish, or lemon hue, for which the weld yellows are particularly valued: this, however, may be readily and cheaply obtained, in the *utmost perfection,* from quercitron bark, by means which will hereafter be explained.

Wool or cloth, which has been first properly dyed blue in the common indigo vat, may be

made to receive any of the various shades of green which are usually given in this way from weld, by boiling the blue wool or cloth, (after it has been well rinced,) in water, with about one-eighth of its weight of alum, as just directed for producing a yellow, and afterwards dyeing it unrinced, with about the same quantity of bark, and a little chalk, which should be added towards the end of the process, as already described. Greens of less body may be dyed with smaller portions of bark and alum.

In the same way, cloth which has previously received the proper shade of Saxon blue, may be dyed of a beautiful Saxon green: it will be proper, however, for this purpose, that the blue cloth should be first very well rinced to separate, as far as water will do it, the acid which may have been imbibed from the sulphate of indigo, and which has a strong tendency to throw down and weaken the quercitron as well as the weld yellows. But as mere rincing in water will separate only a small part of this acid from the cloth, (with which it combines in a certain degree,) it will be proper to add about three pounds of chalk, with ten or twelve pounds of alum, for the preparation liquor of 100lb. weight of cloth, which is to be turned and boiled as usual for about an hour; and then, without changing the liquor, ten or twelve pounds of bark, powdered and tied up in a bag, may be put into it, and

the dyeing continued, taking care frequently to agitate the bag, in order that the colour of the bark may spread equally through the liquor. It will be found, however, that the yellow will manifest itself but slowly in this way, by reason of the sulphuric acid imbibed with the blue colour, joined to that of the alum in the preparation liquor, which the portion of chalk, before mentioned, will not have been sufficient to overcome; and, therefore, when the dyeing with bark has continued about fifteen minutes, it will be proper to add another pound of clean powdered chalk, stirring it well through the liquor, and to repeat this addition afterwards once, twice, and even three times, at intervals of six or eight minutes, if the colour does not rise sufficiently without it. By these additions, the quercitron yellow will manifest and apply itself abundantly and equally, so as to produce very beautiful greens, which, by varying the proportions of indigo, as well as of bark and alum, may be varied at pleasure. The chalk, in this case, does not merely answer the purpose of separating the acid left in the cloth by the sulphate of indigo and the alum, but, by uniting with this acid, it becomes a sulphate of lime, and fixes itself, in part at least, as a basis in the fibres of the cloth, where it helps to raise the colour, and also to render it a little more durable. At present the Saxon greens are commonly dyed with the old

fustic, because the colour of this wood is not thrown down by acids so much as that of the bark and weld: and this difference enables the dyer, when he has extracted the fustic colour by previous boiling, to mix the sulphate of indigo therewith, and dye the cloth green by one operation, after it has been prepared as usual with alum and tartar. The process, however, which I have mentioned for doing this with bark, is full as cheap and as expeditious, and the green produced will be more beautiful, because the quercitron yellow is much more bright and clear than that of fustic.

At pages 83and 84 of this volume I have described a method of combining the Prussian blue and the quercitron yellow upon analumnious basis, so as to produce a beautiful green colour, which I had flattered myself might be advantageously employed upon wool: further trials, however, have manifested so much difficulty in applying the colour equally, that I shall say no more of this combination at present.

Durable yellows may also be dyed upon wool, with either the muriate, the nitrate, or the acetite of alumine, but not with any superiority of colour which could compensate for the increased expence of these aluminous preparations.

Of the best Methods of dyeing upon Wool and Woollen Cloths with Quercitron Bark and the Tin Basis.

In Chapter IV. of Part II. I have mentioned the different effects of some of the preparations of tin in exalting the colour of the quercitron bark, as well as that of cochineal; and it will be remembered that, *for this purpose*, I found the muriate and the murio-sulphate of tin, preferable to any other of the preparations of that metal; I observed, however, that the former of these had an injurious action upon the fibres of wool and cloth, unless when sparingly and carefully employed, and was, therefore, less proper for general use than the solution of tin, made by a mixture of muriatic and sulphuric acids, as described at page 483 of my first volume; to which my readers will be now pleased to recur.

In order to dye 100lb. weight of cloth or woollen stuffs of the highest and most beautiful orange yellow, only 10lb. weight of quercitron bark, and the same weight of murio-sulphate of tin, will be required; the bark powdered and tied up in a bag, may be first put into the dyeing vessel with hot water, for the space of six or eight minutes, then the murio-sulphate of tin may be added, and the mixture well stirred for two or three minutes; after which the cloth may

be put into the dyeing liquor and turned briskly for a few minutes: the colour applies itself in this way, so equally to the cloth, and at the same time so quickly, that after the liquor begins to boil, the highest yellow may be produced in less than fifteen minutes, without any danger of its proving uneven. High shades of yellow, somewhat approaching to those dyed from bark, in the way just mentioned, are frequently given with the rhus cotinus, (commonly, though improperly, called young fustic,) and the dyers' spirit, or nitro-muriate of tin; but the colour so given, is less beautiful and more fugitive, as well as more expensive, than that obtained from the bark, as just described.

When a very bright golden yellow, approaching less to the orange, is wanted, seven or eight pounds of murio-sulphate of tin, with about five pounds of alum, and ten pounds of bark, will suffice for 100lb. of cloth; the bark being first boiled a few minutes, then the murio-sulphate of tin, with the alum added, and the cloth afterwards dyed, as just directed. Pure bright yellows, of less body, may be produced by employing smaller portions of bark, murio-sulphate of tin, and alum, in the same way: and, indeed, all the possible shades of *pure bright yellow* may be given, with the utmost ease and certainty, by only varying the proportions of these ingredients. But where it is expedient to

give that *lively, delicate greenish tinge*, which, for certain purposes, is so much admired, and which the weld alone has been supposed capable of giving, white argol, or tartar, must be also employed with the bark, murio-sulphate of tin, and alum, in different proportions, according to the particular shade intended to be given. Thus, e. g. for a full bright yellow, delicately inclining to the greenish tinge, it will be proper to employ about eight pounds of bark, and six pounds of murio-sulphate of tin, with six pounds of alum, and four of clean white tartar, or cream of tartar; a little more alum and tartar will render the yellow more delicate, and give it more of the greenish tinge; and where this clean, lively, delicate greening tinge is wanted in the greatest possible perfection, it will be proper to use the bark, murio-sulphate of tin, alum, and tartar, all together in equal quantities. These last delicately-greenish lemon yellows, are but very seldom, if ever, wanted to be dyed of much fulness or body, and therefore ten pounds of bark, and the like quantities of murio-sulphate of tin, alum, and tartar, will generally prove sufficient to dye three or four hundred pounds weight of cloth or woollen stuffs of the colours in question; for which purpose the bark is to be first boiled a few minutes in water only, then the other ingredients are to be added, and mixed in the liquor by stirring, and a few minutes boiling,

and afterwards the cloth put into the liquor (first cooled a little) and turned briskly through it until the colour appears sufficiently raised. The pieces intended for the highest shades should be always dyed first, and those for weaker shades afterwards. When about two-thirds of the whole quantity of cloth has been dyed, it will generally be found, that the liquor, by continuing to extract colouring particles from the bark, has acquired an over-proportion of the latter, and wants a small addition of murio-sulphate of tin, alum, and tartar, (perhaps a pound of each,) to enable it to give the same delicately pale, though lively, greenish tinge, as at first: and indeed, a surer way of giving these very pale greenish shades with exquisite delicacy and beauty, is to boil the bark with a small proportion of water in a separate tin vessel for the space of six or eight minutes, then add the murio-sulphate of tin, alum, and tartar, and boil them all together for about fifteen minutes, and afterwards put a little of this yellow liquor into a dyeing vessel, previously supplied with water sufficiently heated, and the mixture being properly stirred, to begin dyeing the cloth as usual, adding farther supplies of the yellow liquor from the first vessel, by a little at a time, as fast as it may be wanted. In this way the palest and most delicate shades may always be dyed with ease and certainty; and those who have never

seen the effects of this process, will hardly conceive the exquisite beauty and delicacy of these pale, but lively, greenish lemon yellows, which certainly cost less than any similar colours given, if such can be given, by any other means. Weld is unquestionably the only dyeing ware capable of producing effects similar to those of the bark in this respect, and at the average price it will prove nearly four times as costly, regard being had to the smaller portion of colour which it affords, besides the expence of long boiling, which the bark does not want, to extract its colour. Indeed, it may generally be computed, that the yellows dyed from quercitron bark, with murio-sulphate of tin and alum, do not cost, in dyeing materials, more than one penny for each pound of cloth, and that in time, labour, and fuel, they do not cost half as much as those usually given by other means. And this is also true of the more delicate shades given by bark, murio-sulphate of tin, alum, and *tartar;* for though this last ingredient be expensive, it is wanted only for the paler colours, which require smaller portions of dyeing materials, and, therefore, do not cost more than the highest shades given without it.

A greenish tinge may, indeed, be produced without tartar, by employing in its stead, a little verdigrise dissolved by vinegar along with the bark, &c. but I think it is neither so lasting

nor so delicately clean and beautiful as that produced by the use of tartar. The sulphate of indigo will also produce this greenish tinge, if employed in a very small quantity with the bark, murio-sulphate of tin, and alum; but it has a tendency to fix itself so quickly upon the fibres of wool or cloth, that great care is necessary to hinder it from taking unequally, and the tinge produced by it is, moreover, somewhat liable to cast or fly, as the dyers say, in the finishing part; whilst the greenish tinge resulting from the use of tartar, as before directed, will leave the press perfectly clear and bright. Indeed, the colours obtained from quercitron bark by these means, are very durable; they withstand even the action of strong mineral acids, and of boiling soap-suds, as well as exposure to air. This last, indeed, they are principally enabled to resist by the good effects of alum, and more especially of tartar. Since the highest yellows, which approach very nearly to the orange, and which are best dyed either with muriate, or murio-sulphate of tin, and bark, though they bear the action of soap and of acids in a wonderful degree, are liable, after some time, to lose a considerable part of their lustre, and acquire a brownish complection by exposure to the sun and air. This is also true of yellows dyed with nitro-muriate of tin (dyers' spirit) as a mordant, not only when employed with the

bark, but with weld, and in a greater degree with fustic and other yellow vegetable colouring matters. In some of which this defect is not so well obviated by alum and tartar, as it is in the quercitron and weld yellows.

I must here remark, that tin, by whatever means dissolved, when applied as a basis for dyeing wool, renders the fibres a little harsh; so that they never run so far nor so easily in spinning as they would otherwise do, and the wool itself is apt to appear coarser; which is one reason for not dyeing scarlet in the fleece, and it may be one for not dyeing wool yellow with any of the solutions of tin as mordants, until it has been woven, or at least spun; though, I am persuaded, this defect is in a great degree obviated, by employing the murio-sulphate of tin, with a mixture of alum, or of alum and tartar, and combining these with the colouring particles of the bark, (in the ways which I have described,) *before* they are applied to the wool or cloth.

When yellows not quite so lively and beautiful can be made to answer, a much smaller proportion of the sulphate of tin will prove sufficient; five pounds thereof, for instance, may be boiled with ten pounds of bark, ten pounds of alum, and two or three of tartar, and the cloth dyed as before directed. The decomposition and recomposition which result

from a mixture of tartar with murio-sulphate of tin, will be readily conceived from what has been mentioned on this subject in the preceding chapter.

By using very small proportions of cochineal with the bark, murio-sulphate of tin, &c. the colour may be raised to a beautiful orange, and even to an aurora. Madder also employed in this way, raises the quercitron yellow, but the effect is less beautiful than with cochineal; and this is also the case when madder is employed with weld.

At pages 381 and 382 of my former volume, I have made some mention of the means of dyeing woollen cloth topically or partially; and since that time I have found, that by mixing a strong decoction of the bark, with a suitable proportion of murio-sulphate of tin, &c. and thickening the mixture, as for the pro-substantive topical yellows, hereafter to be described, for calico-printing, then applying the mixture by a pencil to the woollen cloth, covering the pencilled parts with paper, so as to prevent the moist colour from spotting the other parts, afterwards folding up the cloth, and tying it in a bag made of that kind of oiled linen, which is used for bathing caps, so as to exclude water, and then keeping it immersed in boiling water for a quarter of an hour, a full and beautiful yellow was fixed upon the parts which had been

pencilled, without any farther running or spreading of the colour. The same mixture pencilled upon cloth which had been previously dyed Saxon blue, produced a beautiful green where it had been pencilled. Diluted sulphate of indigo pencilled upon scarlet cloth, and treated in the same way, produced a full black; and it seems to be easy, by employing proper mixtures in this way, to produce all the varieties of colours topically upon woollen stuffs: as far as I can judge, the oiled linen, which, I believe, was never before employed for this purpose, is much more suitable to it than any means now in use.

The most beautiful Saxon greens may be produced very cheaply and expeditiously by combining the lively yellow which results from quercitron bark, murio-sulphate of tin, and alum, with the blue afforded by indigo when dissolved in sulphuric acid, as for dyeing the Saxon blue.

To produce this combination most advantageously, the dyer, for a full-bodied green, should put into the dyeing vessel after the rate of six or eight pounds of powdered bark, (in a bag) for every 100lb. weight of cloth, with only a small proportion of water, as soon as it begins to grow warm; and when it begins to boil, he should add about six pounds of murio-sulphate of tin, (with the usual precautions,) and a few

minutes after, about four pounds of alum; these having boiled together five or six minutes, cold water should be added, and the fire diminished so as to bring the heat of the liquor nearly down to what the hand is able to bear; and immediately after this, as much sulphate of indigo is to be added as will suffice to produce the shade of green intended to be dyed, taking care to mix it thoroughly with the dyeing liquor by stirring, &c.; and this being done, the cloth previously scoured and moistened, should be expeditiously put into the liquor, and turned very briskly through it for a quarter of an hour, in order that the colour may apply itself equally to every part, which it will certainly do in this way with proper care. By these means, very full, even, and beautiful greens, may generally be dyed in half an hour; and during this space, it is best to keep the liquor at rather less than a boiling heat. Murio-sulphate of tin, is infinitely preferable, for this use, to the dyers' spirit; because the latter consists chiefly of nitric acid, which by its highly-injurious action upon indigo, would render that part of the green colour very fugitive, as I have found by repeated trials. But no such effect can result from the murio-sulphate of tin; since the muriatic acid has no action upon indigo, and the sulphuric is that very acid which alone is proper to dissolve it for this use.

Respecting the beauty of the colour thus produced, those who are acquainted with the unequalled lustre and brightness of the quercitron yellows, dyed with the tin basis, must necessarily conclude, that the greens composed therewith will prove infinitely superior to any which can result from the dull muddy yellow of old fustic: and in point of expence, it is certain that the bark, murio-sulphate of tin, and alum, necessary to dye a given quantity of cloth in this way, will cost less than the much greater quantity (six or eight times more) of fustic, with the alum necessary for dyeing it in the common way; the sulphate of indigo being the same in both cases. But in dyeing with the bark, the vessel is only to be filled and heated once; and the cloth, without any previous preparation, may be completely dyed in half an hour; whilst in the common way of producing Saxon greens, the copper is to be twice filled; and to this must be joined the fuel and labour of an hour and an half's boiling and turning the cloth, in the course of preparation, besides nearly as much boiling in another vessel to extract the colour of the fustic, and after all, the dyeing process remains to be performed; which will be equal in time and trouble to the whole of the process for producing a Saxon green with the bark; so that this colour obtained from bark will not only prove superior in beauty,

but in cheapness, to that dyed as usual with old fustic.

Mr. Dambournay, in the supplement to his "Recueil de procedés et experiences sur les teitures solides," &c. mentions various experiments made by him with the quercitron bark, from which he concludes, that in order to produce the good effects which I had previously described as resulting from its use in dyeing woollen cloths, these should be first impregnated with a tin basis, and then dyed in the manner which I had directed. In this way, says he, I obtained full shades of that beautiful yellow, a little greenish, but very durable, ("de cé "beau jaune un peu verdatre et tres solide,") which is so well suited to produce a *fine green*, either by the indigo vat, or by the composition for Saxon blue, i. e. sulphate of indigo. And having applied this latter by the common mode of dyeing, to cloth which had previously received the quercitron yellow, and also to cloth dyed yellow with the Lombardy poplar, (which, in other respects, he greatly commends,) he found that the former which had received the bark yellow, took a fine dragon green, ("un beau "vert dragon,") and the latter nothing better than a greenish olive. It is true that Mr. Dambournay computes the expence of dying with the quercitron bark, as greatly surpassing that of dyeing with the Lombardy poplar. But his com-

putation was founded on very erroneous suppositions, joined to the circumstance of his calculating the muriatic acid to cost near two shillings and sixpence sterling the pound weight, which is more than six times its real cost; though this may, probably, have been nearly the price which it bore in France, whilst the *gabelle* subsisted there.

The nitro-muriate of tin, (dyers' spirit,) though it produces good yellows with quercitron bark, produces them in a much weaker degree than the murio-sulphate of that metal; which is really the cheapest, and most efficacious, of all the solutions or preparations of tin, for dyeing the quercitron as well as the cochineal colours.

The sulphuric acid by itself dissolves, or rather calcines, a large portion of tin, if allowed to act upon it for any considerable time; and this solution, joined to the bark, with alum and tartar, produces bright strong yellows on cloth, though I think they appear less soft and beautiful, than those dyed either with the muriate, or murio-sulphate of tin. This metal dissolved, or rather calcined, by a mixture of the nitric and sulphuric acids, is still less suitable for dyeing with the bark.

Tin dissolved by muriatic acid, to which one-third of its weight of clean white tartar had been previously added, produced a very bright

and delicate yellow with the bark, upon cloth, and this, by longer boiling, was raised to a full and beautiful orange. Tin dissolved in strong nitric acid, (double aqua fortis,) with an addition of one third of its weight of tartar, also produced a very good yellow, though somewhat inferior to the last.

Upon putting tartar, with a portion of tin, into a glass vessel with strong colourless sulphuric acid, the latter, or rather its oxygenous part by combining with the inflammable part of the tartar, immediately rendered the mixture as black as ink; and the solution of tin produced by it, was found of but very little use as a mordant for dyeing with the bark.

The oxyd of tin, produced by the action of the nitric acid upon that metal, contains a large portion of oxygene; and yet it raises the quercitron yellow: but when this oxyd is dissolved in muriatic acid, it produces only a very feeble lifeless yellow with bark; though tin not previously oxygenated will, when dissolved by the same (muriatic) acid, act most powerfully in exalting the quercitron yellow: which seems to prove, that this defect of colour does not result from the presence of oxygene alone, but from its combination with muriatic acid. A similar effect was also produced by employing tin calcined by sulphuric acid, and then dissolved in the muriatic, as a mordant with the bark.

Cloth boiled in water with the muriate of tin and tartar, has sometimes been made yellow, and sometimes of a chesnut brown, *only* from the action of this mordant, unassisted by any colouring drug. These discolourations seem to depend upon the particular state of the cloth, as being more or less freed, either from the natural swint of the wool, or the grease commonly applied to it for particular purposes. Discolourations of this kind are not easily removed; they withstand the action of sun and air for a considerable time, and if cloth so discoloured be dyed with either bark, or with cochineal, the colour will appear tarnished; for which reason the application of muriate of tin, with tartar *only*, as a mordant, ought to be avoided, unless the dyer be very certain that the cloth has previously been perfectly well scoured.

A few lumps of the dry oxyd of tin, mentioned at pages 214 and 215 of the former volume, having been finely powdered and mixed with a suitable quantity of decoction of quercitron bark, the mixture was found capable of dyeing a very full and bright yellow upon woollen cloth. The colour, however, being exposed to the action of sun and air, very soon acquired a brownish complexion. Some of the same oxyd of tin reduced to powder, having been washed in warm water, to remove the adhering acid, as far as water could remove it, was found

to be still capable of combining with the colouring matter of the bark, so as to dye cloth yellow; especially when the oxyd had been previously suffered to remain mixed with the decoction of bark, for some hours, in a warm situation. Cotton also took a yellow colour by dyeing in this mixture; but it was easily removed by washing with soap, and therefore was, I think, only applied superficially.

I have but little to offer respecting the use of copper, or rather of the oxides and solutions of that metal *alone*, as mordants or bases for dyeing with quercitron bark on wool or cloth. Their general effect is to raise and fix the quercitron yellow; but at the same time to give it a greenish or rather an olive tint. Wool dyed with a tenth of its weight of bark, and half as much sulphate of copper, received an agreeable colour, between the yellow and the olive. The bark, with muriate of copper, seemed to impart but little colour to wool for some time; but a little chalk being added, a full yellowish olive was produced. This also proved to be the case, when nitrate of copper was employed with the bark, until chalk had been added; and then the wool speedily imbibed a yellow, delicately inclining to the olive hue. Verdigrise with the bark produced a yellowish olive on wool; which, by the addition of chalk, was brightened, and made

to approach nearer to the yellow. These colours appeared to be sufficiently lasting.

Drab colours of various shades may be most expeditiously and cheaply dyed by the quercitron bark and an iron basis. For this purpose the bark may be boiled a few minutes in a copper vessel, with one-third, or one-fourth of its weight of sulphate of iron, (copperas,) according to the shade required, and the liquor having been well mixed, and a little cooled, the cloth may be dyed therein as usual; but without any other preparation than that of scouring and moistening. To sadden and darken the colour still farther, a little sumach, (rhus coriaria,) may be added with the bark; and on the other hand, the colour may be inclined to the olive and yellow, by diminishing the quantity of sulphate of iron, and employing with it a little alum and chalk; or (which is better) a little sulphate of copper, with or without a small proportion of chalk. Or the cloth may be first turned a few times through a vessel, with boiling bark liquor, then taken out, and turned briskly through a vessel with hot water, in which a suitable proportion of sulphate of iron has been dissolved, with or without either alum and chalk, or sulphate of copper and chalk, as the particular colour intended to be given may require. In either way the colours will prove lasting, and the expence very small; four or five

pounds of bark being generally sufficient to dye one hundred pounds weight of cloth, of the colours in question. Cloth prepared by previous boiling, with one-twentieth of its weight of sulphate of iron, and one-fourth of that quantity of chalk, and then dyed in bark liquor, became of a strong durable chocolate colour; but in this way great care is necessary to render the colour even.

Cloth prepared by boiling with a twentieth of its weight of sulphate of iron, half as much sea-salt, and one-fourth of that quantity of chalk, and then dyed with bark, received a very lasting dark brown colour.

Cloth dyed with quercitron bark, sulphate of iron, and sulphate of manganese, in small proportions, became of a light, but pleasing, drab colour; which, by the addition of a little chalk, was afterwards changed to the cinnamon.

Cloth prepared with nitro-muriate of gold, and dyed with bark, became of a delicate olive yellow. The solutions of bismuth, zinc, antimony, silver, mercury, lead, and platina, by different acids, produced various shades of brown, yellowish brown, brownish yellow, cinnamon, drab, and olive colours; of which it is not expedient to give my readers a particular description, because they either may be all more cheaply obtained by other mordants, or are not likely to be brought into use.

Cloth boiled in water, with one-twentieth of its weight of sulphate of lime, and dyed with bark, received a strong nankeen colour. Nitrate of lime in this way, produced a nutmeg brown; and the muriate of lime produced a very full and lasting drab colour, which, in some respects, may be preferable to the drabs given by an iron basis, and especially as being less likely than the latter to injure the texture of the cloth.

Of the Properties and Uses of Quercitron Bark in dyeing upon Silk.

All the different shades of yellow, commonly dyed upon silk from weld, may be obtained with equal facility and beauty, and more cheaply, by employing the bark in its stead, after the rate of from one or two pounds for every twelve pounds of silk, according to the particular shade of colour wanted. For this purpose the bark, powdered and tied up in a bag, should be put into the dyeing vessel whilst the water is cold, and as soon as it becomes a little more than blood-warm, the silk, previously alumed, should also be put in and dyed as usual; and where the higher yellows are wanted, a little chalk or pearl-ashes may be added towards the end of the operation, as mentioned for the dyeing of wool.

Where shades of yellow, more lively than any which can be given either by weld or bark with

the aluminous basis only, are wanted, it will be advantageous to employ a little of the murio-sulphate of tin; and but a little of it, because the calx of tin, unless sparingly used, always diminishes the glossiness of silk.

To produce the shades in question, it will be sufficient to boil, after the rate of four pounds of bark with three pounds of alum and two pounds of murio-sulphate of tin, with a suitable quantity of water, for ten or fifteen minutes, and the heat of the liquor being afterwards reduced so that the hand can bear it, the silk is to be put in and dyed as usual, until it has acquired the proper shade, (which it will do speedily,) taking care, however, to agitate the liquor constantly, that the colouring matter, which would otherwise subside in a considerable degree, may be kept equally dispersed through the liquor. By adding suitable proportions of sulphate of indigo to this yellow liquor, and keeping it well stirred, various and beautiful shades of Saxon green may be dyed in the same way very equally and cheaply. The shades intended to incline most to the yellow should be first dyed, and afterwards, by adding more sulphate of indigo, those partaking more of the blue may be readily produced; and, indeed, nothing can be more commodious or certain than this way of dyeing the most beautiful Saxon greens upon silk.

By dissolving different proportions of copperas, or copperas and alum, in the warm decoction of bark, silk may, in the same way, be dyed of all the different shades of olive and drab colours; and other varieties may be produced with the bark generally, by employing the same means which are used to produce the like variations with weld.

Of the Application of Quercitron Bark to the Fibres of Linen or Cotton, either woven or spun, by general Dyeing.

I HERE use the term *general* dyeing as opposed to that *partial* or *topical* application of colours on which calico-printing chiefly depends. At pages 90 and 91, of my former volume, I have endeavoured to explain the causes which render adjective colours less durable on linen and cotton than they are on wool or silk, so far, at least, as these causes depend on differences in the structure and chemical properties of the substances in question; but whether my explanation be well founded or not, this at least is certain, that the attraction between the aluminous basis and the fibres of linen and cotton, is much weaker than that which subsists between the same basis and the fibres of wool or of silk; and this want of a sufficient attraction or affinity has made it necessary to employ extraor-

more copiously, and fixing it more firmly, than it otherwise would be precipitated and fixed upon the fibres of linen or cotton, in order to enable them to receive permanent adjective colours by dyeing. The principal of these means are certain oily and animal matters joined to some vegetable astringents, particularly galls; all of which, I mean the former as well as the latter, evidently possess a strong attraction for alumine, and when united to linen or cotton, produce very beneficial effects, as is manifestly seen by the process for dyeing the Adrianople or Turkey red, concerning which Mr. Henry, M. Berthollet, and M. Chaptal, have published several very ingenious as well as highly interesting observations; at present, however, I shall only notice these extraordinary means, so far as they seem likely to improve the beauty and durability of the colours capable of being communicated to linen or cotton from quercitron bark.

The fibres of linen or cotton, when spun or woven, are prepared for the dyer by being first boiled in water with a suitable portion of potash, (which for linen should be made caustic, in order that it may act more strongly upon the oily and resinous matters abounding in flax,) and afterwards bleached by exposure upon the grass to sun and air. But as this operation commonly leaves a portion of earthy matter in the linen or cotton, which, by being unequally

distributed, would render any colour given by dyeing unequal; the cotton or linen ought to be soaked or steeped in water, soured by sulphuric acid, to dissolve and remove this earthy matter, taking care afterwards to wash or rince off the acid, lest, being concentrated in the cloth or yarn when drying, it should injure the texture.

The method prescribed by the French regulations, and adopted in most European countries, for dyeing yellow upon linen or cotton from the weld plant is, by soaking the cloth or yarn in a liquor made by dissolving one-fourth of its weight of alum in as much water as is necessary for that purpose; to which it will be highly advantageous to add, after the rate of one pound of clean potash or ten ounces of chalk, for every six or seven pounds of alum,* to neutralize the excess of acid contained in the alum, and promote a separation of its earthy basis. The cloth or yarn having been thus soaked, is taken out of the alum liquor, and well dried; and being afterwards rinced, it is to be dyed in

* Haussman says, that when English alum is dissolved in five times its weight of water, and one-eighth of its weight of chalk is added to saturate the excess of acid, a solution will be produced, which does not crystalize in summer, and but little in winter; though without chalk it requires sixteen times as much water as of alum to make a permanent solution.

weld liquor made by boiling about one pound and a quarter of the plant for each pound of cloth or yarn; which, after having received a sufficient body of colour, is to be taken out of the dyeing liquor, and soaked for an hour and more in a solution of sulphate of copper, (blue vitriol) containing after the rate of three or four ounces of the latter for each pound of cloth or yarn ; it is then to be removed, and, without being washed, put into a boiling solution of hard soap, containing in like manner three or four ounces of soap for each pound of cloth or yarn, in which it is to be well stirred and boiled for about three quarters of an hour or more, then washed and dryed. I have found, by repeated trials, that this mode of precipitating the calx of copper upon the yellow previously dyed from weld with an aluminous basis, renders the colour more durable, but, at the same time, gives it a darker complexion. And I have found similar effects where bark was used instead of weld ; the colour dyed with the bark in this way having proved, in every respect, as good as that obtained from weld : but I am convinced, that whether the colouring matter be taken from the former or the latter of these vegetables, the yellow dyed in this way never is either so beautiful or so lasting as that partially given by calico-printers from the same vegetables, and which the dyers might readily give with equal perfection, by only employing the acetite of

alumine, or aluminous mordant, described at pages, 359, 360, and 361, of my first volume; and this more cheaply as well as more expeditiously than that produced by following the French regulations; considering the expence of so much blue vitriol and soap as they require, and which may be rendered unnecessary by adopting the calico-printers' aluminous mordant.

The best method of applying the aluminous mordant for general dyeing with quercitron bark (which I most earnestly recommend whenever bright and durable yellows are wanted,) is as follows, *viz.*

Take a sufficient quantity of the acetite of alumine, which for this purpose may be made by dissolving after the rate of *only* one pound of sugar of lead and three pounds of alum, as at the pages just quoted,* excepting only that it need not be thickened, and mix this liquor with an equal quantity of warm water, then let the linen or cotton (properly cleansed, as before mentioned) be thoroughly wetted and soaked in the mixture, which ought to be about blood-warm, for the space of two hours, then taken out and moderately pressed or squeezed over a proper vessel to collect what might otherwise drop or run off, and prevent an unnecessary waste of the aluminous liquor; and this being

* See also the cheaper means of preparing an acetite of alumine, mentioned in the note to p. 366 of Vol. I.

done, let the linen or cotton be well dried in a stove heat, where it can be conveniently applied, and then soaked again in the aluminous mordant, and again pressed or squeezed and dried as before; after which, without having been rinced, let it be thoroughly wetted in as much, and only as much, lime water as will conveniently suffice for that purpose, and afterwards dried; and where a very full, bright, and durable yellow is wanted, it may be well to soak the linen or cotton a third time in the diluted aluminous mordant, and after drying, wet it a second time with lime water, and dry it again: but in either case, the linen or cotton, after its last dyeing, should be well rinced in clean water, in order to separate any loose or unfixed particles of the mordant or basis, which otherwise might do harm in the dyeing vessel. The lime-water employed in this way, answers the purpose of producing a more copious deposition of the alumine in the fibres of the linen or cotton, and it moreover superadds a portion of calcarious to the aluminous basis; an effect which is not without considerable utility.

I have found, that when the aluminous liquor has been employed at a scalding heat, the colour afterwards produced was not so good as that which results from liquor only made blood-warm; the pores of linen and cotton being so open as not to require any distension by a greater degree of heat.

The cotton or linen being prepared and rinced, as before mentioned, a small fire is to be lighted under the dyeing pan or vessel, previously supplied with the usual quantity of water, and the powdered quercitron bark tied up in a bag, after the rate of from twelve to eighteen pounds for every hundred pounds weight of linen or cotton, where full-bodied yellows are wanted, is to be put in, whilst the water is cold, and immediately after it, the linen or cotton is also to be put in, upon sticks, if it be thread or yarn, or, if piece-work, on the winch, agitating or turning it, in either case, as usual, for the space of an hour, or an hour and a half, during which the water should gradually become warm, but not warmer than the hand can bear. When this time has elapsed, the fire may be increased, and the dyeing liquor brought to a scalding, and thence to a boiling heat; in which it will be sufficient to let the cotton or linen remain a few minutes only, when a bright lively yellow is wanted, because longer boiling always gives the yellow a brownish cast, whatever vegetable may be employed in dyeing it. The linen or cotton having thus acquired sufficient colour, is to be taken out, rinced, and dried as usual.

When the colour of quercitron bark is slowly raised in this manner by a very moderate heat, the colouring particles seem to adjust themselves more accurately, and unite more intimately, to

those of the basis, and thereby to produce a colour more fixed and durable than it is when they are hastily accumulated by a boiling heat, and, perhaps, chiefly upon the surface of the substance dyed, and of the basis combined therewith.

All the different shades of yellow may in this way be dyed from quercitron bark: if it be used sparingly, with a very moderate heat, and the operation continued only for about half an hour, a pale, though lively, yellow will result; if used more copiously, and the operation continued somewhat longer, a fuller colour will be produced; and this may be raised higher and higher according as the heat and proportion of bark are increased and the dyeing operation prolonged, so as, indeed, to produce a very dark brownish yellow, if the liquor be made to boil for half an hour.*

Pieces of cotton having been prepared with the printers' aluminous mordant and lime water, as already described, were dyed one with bark and another with weld, and being taken out of the dyeing liquors, a bit was cut off from each,

* M. Chaptal appears to think that lime may be usefully employed to extract, raise, and fix the colour of quercitron bark. He says, that having added quick lime to a decoction of this bark it produced "un magma d'une *magnifique* couleur jaune, qui jouit d'une assez forte fixite et dont on peut tirer une grande parti dans la teinture." See his Chimie appliquée aux arts. tom. iv. p. 460.

and the remainder put back again into its liquor, in which a small quantity of sulphate of copper had, in the mean time, been dissolved, (after the rate of one ounce to five pounds of cotton,) and the liquors being nearly of a scalding heat; in about ten minutes the pieces were again taken out and found to have acquired a brownish complexion; but, being exposed to the sun and air along with the bits which had been cut off before the sulphate of copper was added to the dyeing liquors, the brownish complexion of the former soon disappeared, and their remaining colour, at the end of four weeks, proved to be rather better than that of the bits dyed without the sulphate of copper. It seems, therefore, probable, that a sparing use of the latter in this way, may contribute something at least to the durability, if not to the beauty, of yellows dyed upon linen or cotton, *after* the application of acetite of alumine and of lime, as before directed.

When the aluminous mordant is employed without any addition of water, it may be sufficient to soak the cotton therein *once* only, and after dyeing to immerse it *once* in lime water then dry, rince, and dye it, as before mentioned. I think, however, that better effects result from, the application of a more diluted mordant, *at two different times*; and, indeed, I have found, that by immersing the cotton *a great number of times* alternately in the diluted aluminous mordant

and in lime water, and drying it after each immersion, the colour always acquired still more body and durability.

At page 370 of my former volume, I have remarked, that by the East Indian method of calico-printing, the want of acetite of alumine is supplied by impregnating cotton with the astringent matter of yellow myrobalans, and with certain oily and animal substances, which enable the cotton, when a solution of alum is afterwards applyed to it, to decompose and imbibe a larger portion of alumine: and this practice may be imitated in dyeing the quercitron yellow upon cotton, with so much advantage as to render the acetite of alumine in a great degree unnecessary, at least where the yellow is not required to be very clear and bright.

Instead of myrobalans, (which are, however, to be found here,) the Alleppo galls may be employed, choosing always the whitest for this use, because the browner might stain the cotton, so as to render it incapable afterwards of receiving a bright clear yellow; and, perhaps, in this respect, the roots of at least two or three species of North American sumach, particularly the rhus glabra, Lin. might be preferable even to the whitest galls, by communicating less stain, and producing equally good effects, as I have found them to do in repeated trials.

The best method of employing galls for this

dinary means for precipitating the alumine purpose is, I believe, to boil after the rate of one pound of them, coarsely powdered, with half a pound of barilla, for the space of one hour, in two or three gallons of soft water, and then straining off the decoction to macerate the cotton an hour or two therein; barilla, or rather the soda which it contains, enables the water to extract the astringent matter of the galls much more copiously than it otherwise could do; and being itself imbibed by the cotton, it also occasions a more plentiful deposition of alumine, when the cotton is afterwards put into a solution of alum, which, for this use, may be made by dissolving eight pounds of alum and one pound of chalk in six gallons of water. In this calcareous solution of alum, the cotton, after being taken out of the decoction of galls and dried, is to be soaked for two hours, then taken out and dried; then soaked a few minutes in lime water, and having been again dried, it is to be immersed a second time in the calcareous solution of alum; after which, being again dried and well rinced, the cotton is to be dyed slowly with the quercitron bark, as before directed. In this way very full-bodied and lasting yellows may be obtained, which will bear repeated washings with soap, as well as exposure to sun and air; and the action of strong vinegar.

By dissolving after the rate of one pound of

hard white soap, and half a pound of barilla, in three gallons of water, and macerating the cotton therein, as directed to be done with the decoction of galls and sumach, then drying and immersing it in calcareous solution of alum, and afterwards proceeding, as just directed to be done after such immersion, I obtained a colour (with the bark) nearly as durable as when the decoction of galls had been used, and with the advantage of its not being thereby *darkened.*

A pound of the yolks and whites of eggs, having been first beat up with an equal quantity of brown sugar, and then with two gallons of water, and cotton having been soaked therein, instead of the solution of soap and barilla, then dryed and immersed in the calcareous solution of alum; dried again and immersed in lime water, and then in the solution of alum, and afterwards rinced, and dyed with bark, as already described, it received a very full and lasting, though darkish, yellow colour. The animal mucilages in general, and some of the vegetable, being dissolved in water and applied to cotton in the same way as the yolks and whites of eggs, just mentioned, produce the like good effects, and more especially the animal glue; which appears to unite both with the cotton and the aluminous basis when used in this way.

A considerable time has now elapsed since I was induced to try the effects of alumine com-

bined with other acids, besides the sulphuric and acetous, and also with potash, soda, and ammonia, both in their mild and their caustic states, as a basis or mordant for the quercitron colouring matter. To separate alumine from the sulphuric acid with which it forms common alum, this last compound may be dissolved in about eight times its weight of clean boiling water, and mixed with a filtered lixivium of clean potash, which should be added to the solution of alum gradually, until it no longer makes the liquor turbid, or occasions any further precipitation of alumine. The whole of the mixture may then be put into a canvas strainer to separate the fluid part, and this having been done, boiling water may be poured repeatedly upon the remaining moist alumine, and suffered to run through the strainer until the saline part of the mixture shall have been washed away, as far as it is capable of being washed away by water; the alumine being then taken out and dried, will generally be found to weigh about one-fifth part of the weight of the alum employed to produce it: when thoroughly dried, the alumine contracts or shrinks greatly, and becomes at length so hard, that neither strong sulphuric or nitric acids can dissolve it, except with great difficulty and very slowly; and for this reason it ought always to be employed in a moist state, when intended to be again dissolved by any acid or

alkaline menstruum. Perhaps the great disposition of this earth to contract or shrink by drying, may be one reason why it is generally most advantageous to convey and fix the particles thereof as a basis in the pores of linen or cotton, *first* separately, and afterwards, when they have shrunk by drying, to superadd the adjective colouring matter, which may then find more space, and combine with the alumine in greater proportion than it could do when both, previously united, were applied together, whilst the particles of alumine were enlarged by moisture.*

If moist alumine, obtained in the manner just described, be dissolved in either the nitric or muriatic acids, it will, by evaporation, afford crystals; and those obtained with the nitric acid, by attracting moisture from the atmosphere, will prove deliquescent, unless kept in a vessel closely stopped. M. Berthollet found, that in these cases, the crystals depended on a remnant of sulphuric acid, which always adheres to alumine, when separated in the way just described; and

* Another cause seems to be this, that when the colouring matter and the basis are first separately united, their affinities are exclusively exerted upon, and satisfied with, each other; and when they are afterwards applied to the stuff intended to be dyed, they have less attraction for it, and the size of their combined particles being increased by this union, they do not precipitate so far or so copiously.

that, by afterwards digesting it for some time in a solution of potash, or of ammonia, this adhering sulphuric acid might be decomposed; and that the alumine being then dissolved, either in the nitric or the muriatic acid, no crystals were produced. It must, however, be remarked, that the alumine mentioned to have been employed in the succeeding trials, was obtained in the way first described, and, therefore, was not completely divested of sulphuric acid.

Having boiled a suitable portion of moist alumine with a decoction of quercitron bark during the space of half an hour, I attempted to dye both wool and cotton therewith, in order to see whether the undissolved particles of alumine, so united to the colouring matter of the bark, would become the basis of a lasting colour. I found, however, by repeated trials, that cotton in this way could only be made to imbibe a pale yellow, which, probably, adhered to the surface only of its fibres, because it was nearly destroyed by a single week's exposure to the sun and air. Wool, however, in this way received a brownish yellow, of sufficient body and considerable durability.

Ammonia, or volatile alkali, whether mild or caustic, appears to dissolve alumine so very sparingly, that hitherto I have found no considerable benefit from any solution of this kind as a mordant. Nor have I succeeded much better with either the carbonated (mild) potash,

or that of soda, their action not being considerable upon the earth of alum. But if this earth, obtained by precipitation and washing, as before mentioned, be digested whilst moist with a strong lixivium either of potash or of soda, in its pure or caustic state, in a matrass placed on a sand heat, nearly approaching that of boiling water, it dissolves very copiously, and may afterwards, by evaporation, be made to crystalize. The celebrated Macquer appears to have believed, that very beneficial effects might be obtained in dyeing by these combinations, and more especially when used as mordants for the madder red on cotton. It seems evident, however, that he was greatly mistaken respecting the true nature of those operations, upon which this belief was founded; and that in the process for Turkey reds, where he supposed the durability of colour to result principally from a combination of this kind, no solution of aluminous earth by any alkaline menstruum could have taken place; and though Mr. Haussman appears also to have formed considerable expectations of advantage from the application of these solutions of alumine by potash or soda, I have been led, by the results of many trials, to concur in opinion with M. Berthollet, that but little good is to be expected from them, unless it be under the circumstances which I shall

presently explain, because the alkaline menstruum evidently has too much affinity to the particles of alumine to allow of their being deposited and fixed in the substance, to be dyed so copiously as is necessary; and I have repeatedly found, that after having soaked cotton a sufficient time in the diluted solution of alumine by either potash or soda, the basis was almost wholly carried off, or removed by only rincing the cotton in water to fit it for being dyed, and that only very feeble colours could be raised upon what remained of the alumine as a basis. This was more especially the case where the solution of alumine had been made by potash, which, by attracting moisture from the atmosphere, rendered it difficult to dry the cotton sufficiently when impregnated therewith, at least without artificial heat. These defects were, however, removed, and a *very excellent durable yellow* produced, by putting the cotton, which had been *first* soaked, in a diluted solution of alumine by potash, into water which had dissolved as much common alum as it could retain, whilst blood-warm, macerating and turning it therein for the space of half an hour, (during which the potash and sulphuric acid combining, each precipitates the alumine of the other,) then drying the cotton, and afterwards immersing it in lime-water; then drying again, rincing and dyeing it with the bark, as before directed. The yellow given in this

way faded but very little by two months exposure to sun and air in the midst of the Summer; nor was it sensibly weakened by the action of strong French vinegar, or of the oxygenated muriatic acid. The solution of alumine by soda produced equally good effects in this way.

Nitrate of alumine (made by saturating the nitric acid with moist alumine, as before mentioned,) being dissolved in eight times its weight of water, and used instead of the solution of common alum, last mentioned, produced a yellow rather better and more durable, even, than the last. Cotton, which had received no impregnation, being macerated in a like solution of the nitrate of alumine, then dried, immersed in lime water, rinced, and dyed with the bark, received a yellow considerably better than I could obtain with a solution of common alum in the same way.

Muriate of alumine generally produced with the bark, effects as good, but not materially better, than those resulting from common alum used in the same ways.

In dyeing any of the yellows before mentioned with bark, the colour may be raised to an orange by employing a suitable proportion of madder along with the bark.

It can hardly be necessary for me to mention, that linen or cotton, either spun or wove, when previously dyed blue of a suitable shade in the

usual ways, will be rendered green by superadding the quercitron yellow in the ways, and by the means, already directed for dyeing thi yellow upon linens and cottons, not previouly made blue, taking care to proportion the quantum or body of each of the component blue and yellow colours to the particular shade of green which they are intended to compose or produce.

Linen and cotton soaked four hours in a mordant made by dissolving lime in muriatic acid, and mixing the solution with six times its weight of water, afterwards dryed, rinced, and dyed with quercitron bark, took a full drab colour, which resisted the action of sun and air for a considerable time: but neither the sulphate nor the nitrate of lime employed in this way with the bark, gave any thing more than buff or slight nankeen colours, of little durability.

Magnesia dissolved by the sulphuric, the nitric, muriatic, and acetous acids, and used in this way as a mordant, produced, with bark, upon linen and cotton, weak drab, cinnamon, and nankeen colours, which, however, proved too fugitive to be of any use.

Cotton, soaked in a diluted solution of flints, made as formerly mentioned, and afterwards rinced and dyed with the bark, became of a nankeen colour somewhat lasting.

Among the metallic bases, that of tin might

be expected to produce benefical effects by *general dyeing* upon linen and cotton with the quercitron bark; but hitherto my experiments therewith, though they have been very numerous and greatly diversified, afford no successful results: for though different solutions of tin, (particularly the nitro-muriatic and the murio-sulphuric,) when diluted and applied as mordants to linen and cotton, enabled these substances afterwards to imbibe yellows exceeding all others in brightness, lustre, and beauty; and though these yellows are capable of resisting the action of boiling soap-suds, as well as of strong acids, not excepting the oxygenated muriatic acid, yet they decay very speedily when exposed to the sun and air, so as even to suffer more in a single week than the quercitron yellows dyed upon an aluminous basis commonly suffer in a month. The tin basis is, moreover, accompanied with this *singular* circumstance, that when applied separately to the linen or cotton intended to be dyed, and when these substances, after the usual drying and rincing, are dyed with the bark, the colour (contrary to what happens with the aluminous basis) proves much more fugitive than it does when the solution of tin and decoction of bark are first mixed together, and afterwards applied to the linen or cotton prosubstantively; nor have I ever been able to apply any of the solutions of tin, even in small quantities, mixed with an

aluminous mordant upon linen or cotton, without perceiving that the colour afterwards obtained thereby from bark, was much less durable in respect to sun and air, than it would have been with an aluminous basis only.

Zinc, dissolved by different acids, and employed as a basis for dyeing with quercitron bark on linen and cotton, produces brownish yellows, inclining more or less to the olive and drab colours; they seem, however, less durable than the like colours, which may be more conveniently and cheaply given by substituting solutions of alum and of iron, mixed in different proportions, as mordants.

Bismuth being dissolved in nitro-muriatic acid, and the solution afterwards sufficiently diluted by water, and cotton being soaked therein for two hours, then immersed in lime-water, dried, rinced, and dyed with quercitron bark, it took a very high and full, but at the same time a brownish yellow, of considerable durability.

Copper, dissolved in the sulphuric, the nitric, muriatic, and acetous acids, and afterwards sufficiently diluted with water, being applied to linen and cotton as a mordant, enables them to obtain from quercitron bark, by dyeing, different shades of full, but brownish yellow, which, however, does not long bear washing with soap, or exposure to rain, sunshine, and air; the oxyd of copper on which the colouring matter is ap-

plied, being readily acted upon by all these agents. Soaking the linen or cotton in lime-water, when impregnated with the oxyd or solution of copper, previous to the dyeing with bark, renders the colour more durable.

Cotton, having been soaked two hours in a diluted ammoniate of copper, and then hung out to dry, appeared at first of a fine blue colour, but afterwards became of a very beautiful bluish green. A bit of this cotton being dyed for a few minutes in a decoction of quercitron bark, became of a fine yellowish green: another bit dyed in the same decoction for a longer time, became of a dark brownish yellow colour; this was, however, changed to a lively yellowish green, by washing with soap, and suffered but little during three weeks exposure to sun-shine, air, and rain.

Linen or cotton soaked in a diluted nitrate of lead, then in lime-water, and afterwards rinced, and dyed with quercitron bark, took a kind of nankeen brown colour, somewhat, though not very, durable.

The other solutions of lead, appear to be still less useful as m dants upon cotton, for dyeing with the bark.

Manganese being dissolved by a very weak or diluted sulphuric acid, and the solution afterwards mixed with an additional portion of water, cotton was soaked therein for two hours,

and afterwards immersed in lime water, then rinced and dyed with the bark, from which it obtained a nutmeg brown colour, inclining slightly to the olive, which proved somewhat lasting.

The oxyd of arsenic is capable of serving as a mordant for the quercitron colouring matter, but as the shades produced by it may be obtained by cheaper and much less dangerous means, I cannot recommend its use for this purpose.

Cotton, soaked in a diluted nitro-muriate of gold, afterwards rinced and dyed with quercitron bark, received a delicate olive-tinged yellow of considerable durability; but this mordant is much too expensive to be used in this, or in almost any other way.

Cotton, first dipped in a weak solution of soda, became of a yellowish brown by being soaked in a diluted solution of platina by the nitro-muriatic acid, and being afterwards dyed with the bark, it became of an olive colour.

Cotton, dipped in a weak solution of soda, and then in a diluted solution of the grey ore of cobalt, *(cobaltum galena,)* by the muriatic acid, became first green and then yellow; and this being afterwards dyed with quercitron bark, the colour changed to a lasting black. The pure cobalt, dissolved either by the muriatic or the nitric acids, and applied in this

way to cotton, produced a cinnamon brown colour, with the quercitron bark.

Cotton, wetted with a solution of soda, and then with a diluted nitrate of nickle, became green, and being afterwards dyed with the bark, it became of a full cinnamon brown.

Iron, though I mention it last, seems to be the most useful of the metallic bases, for dyeing on cotton and linen with the quercitron bark, and more especially for producing the drab, mud, dove, and olive colours, with the great variety of shades which result from a mixture of these upon cotton velvets, velverets, fustians, &c. These colours have hitherto been commonly dyed from what is called the old fustic, *(morus tinctoria,)* though they may be given more cheaply and conveniently with the quercitron bark in the same ways, and when so given, are more lasting than those given by fustic, as I have repeatedly found by exposing samples of each to rain, sun, and air, for the space of six months together.

The cheapest form in which iron can be employed in this way, is that wherein it is dissolved by sulphuric acid, as in the common sulphate of iron, or green copperas; and, after many trials, I have not found any other combinations of this metal capable of producing effects so much better in dyeing as to compensate for the increased expence attending their use. Copperas

and quercitron bark, in different proportions, produce all the different shades of the *drab* colour, from the deepest to the lightest; and for this purpose, the copperas may be either dissolved in a decoction of the bark, and the pieces of cotton velvet, velveret, or fustian, turned through the liquor (of a suitable heat) by the winch, or the bark may be boiled with water in one vessel, and the copperas dissolved by warm water in another, and the pieces passed as usual, first through the latter, and then through the former, and so alternately from one to the other, until the proper shade is acquired; and by adding after the rate of one pound of chalk to eight pounds of copperas, in the vessel wherein this last is dissolved, the colour will be rendered more durable, and at the same time changed a little to the chocolate brown.

To produce the olive shades, sulphate of copper, (blue vitriol) with about one-eighth part of its weight of chalk, or alum with a like proportion of chalk, may be employed along with the copperas, so as to give the drab colour a sufficient inclination towards the yellow hue; and for this purpose, the blue vitriol is, I think, preferable to alum.

For the drab colours, one or two pounds of copperas, according to the fulness of colour wanted, with about three times as much of bark as

of copperas, and a little chalk, will suffice to dye 100lb. weight of velvet, velveret, or fustian: and for the olives, it will only be necessary to diminish the quantity of copperas according as the shade is wanted to incline more or less to the yellow, and add as much or a little more blue vitriol in its stead: and for this purpose, the blue vitriol may be either dissolved in the same vessel with the copperas, (and chalk,) or it may be dissolved with chalk in a separate (third) vessel, and the velvets or fustians, after they have been turned or worked sufficiently in the two first vessels, containing, one the copperas liquor, and the other the bark liquor, may be turned or worked in the solution of blue vitriol in the third vessel, until it inclines sufficiently to the yellow hue; and, perhaps, this method will generally be found most convenient to fustain dyers, who are frequently required at the same time to dye a great variety of different shades. But otherwise, it probably would be most advantageous to turn and soak the pieces for a little time in the solution of copperas and chalk, or of copperas, chalk, and blue vitriol, (or alum instead of blue vitriol,) then immerse them for a few minutes in lime-water, and afterwards rince and dye them in a decoction of bark, by which colours much more lasting, and much less liable to spot than those commonly obtained, might be dyed; it would, however, be more

difficult in this way to produce that great variety of shades, which in the other are easily attained by any dyer accustomed to the use of old fustic for the like purposes, as I well know by my own experiments, and by those of others. One pound of bark will commonly produce as much effect as four pounds of old fustic.

When darker colours are wanted than can be conveniently given with the quercitron bark and copperas, a portion of Spanish sumach may be added to obtain them, as is done for saddening the colours given with old fustic and copperas; though it is possible to produce a durable colour, approaching very nearly to a *perfect black*, by the quercitron bark and the iron basis, by first soaking the cotton in a weak solution of barilla and liver of sulphur, then drying and immersing it in a diluted solution of iron, by the nitro-muriatic acid, and afterwards dyeing it with the bark.

Of the Application of Quercitron Bark in Topical Dyeing, or Calico Printing.

Between pages 346 and 381 of my former volume, I have given a general, though summary, account of the art of calico printing, as practised during many ages by the inhabitants of India; and also of the improvements which have followed the introduction of this art into Europe. I have also particularly described the two principal mordants or bases employed to fix

and raise the different adjective colours, by topical or partial dyeing; I mean the printers' aluminous mordant, or acetite of alumine, and what is called iron liquor (acetite of iron), made by dissolving that metal in vinegar, sour beer, &c. These mordants the calico printers have very improperly named colour, or colours, though they only afford the basis, or bases, of colour, to be afterwards obtained from madder, weld, quercitron bark, &c. For an account of the preparation of acetate or sugar of lead, and of the substitutes for it, in making the aluminous mordant, I cannot do better than refer my readers to M. Berthollet's chapter on that subject, and to the writers therein mentioned, and, for an account of the true nature and advantage of this aluminous mordant, my readers will be pleased to recur to pages 359, 360, &c. of the former volume. Of the iron liquor, it may be proper to observe, that, when made with vinegar, that which has been longest kept is most esteemed. But of late much is consumed which has been prepared by dissolving iron more expeditiously in the pyro-ligneous acid, obtained by distillation from wood, and it is probable that, in some cases, the action of this acid has been strengthened by an addition of the muriatic, though this last must have a tendency to render the solution corrosive.

Linens or cottons before they are printed,

require to be bleached; and the more perfectly this operation is performed either by the old or new method,* the less will the parts intended to remain white be afterwards stained by the madder, weld, or bark, liquors in dyeing; and the more easily will any discolouration from these liquors be afterwards discharged. After bleaching, the pieces will need to be calendered, in order to produce a smooth surface, and render the woof and shoot as even and square as possible, and thereby favour a due application of the mordants; which, being properly thickened by starch, flour, or gum, as formerly mentioned, are to be applied by blocks, plates, cylinders, &c. as those employed in this part of the business sufficiently understand. This being done, the pieces are to be well dried in a stove heat, so as to evaporate the acetous acid, which held the basis in a state of solution, and cause the latter to be more copiously deposited and fixed in the pores of the cloth.

After drying, the cleansing operation follows; and this is performed in a copper with water, nearly as warm as the hand can well bear, and a quantity of fresh cow-dung; in which the

* M. Widmer, of Jouy, thinks that calicoes bleached by the oxymuriatic acid, not only become whiter, but afterwards take the different colours with better effect than when bleached by other means.

pieces are to be briskly worked, so as to dissolve the thickening of the mordant, or mordants, and separate all the unfixed superfluous particles of alumine, or of iron, which the cow-dung serves to entangle, and thereby hinder them from spreading and attaching themselves to the parts intended to be kept white, and there becoming the basis of a future stain, or discolouration, which it might be difficult to remove; after this, the pieces, being thoroughly soaked and well rinced in clean water, will be fitted for dyeing with the bark.*

In many cases, madder colours are mixed in the same piece with those of the bark; but in these the madder ought to be first dyed on a separate course of work, in which the mordant, or mordants, are printed only so far as the madder colours are intended to extend; and the piece being then dried, cleansed, and dyed with the madder, and afterwards whitened by branning and bleaching, are to be calendered, and made ready to receive a second course of mordants for the bark, in which the pieces are to

* To save time and trouble, calico printers often cleansé (if I may use this term) too many pieces of printed calico in the same deficient quantity of water, (with cow-dung) which thus becomes overloaded with the mordants, containing iron, with galls, logwood, &c. which are frequently mixed with them, and which, by combining with alumine in the parts intended to be dyed yellow, necessarily degrade the latter colour.

be printed, dried, cleansed, &c. as just mentioned.

My readers have been already informed, that the bark produces a good bright yellow with the aluminous mordant, and a drab colour with the iron liquor; and that both together, mixed in different proportions, produce different shades of olive and olive-brown colours. And that if a strong decoction of galls be added to the iron liquor, and the mixture applied in the same way to linen or cotton, it will, by dyeing with the bark, produce a black sufficiently fixed, though inclining a little to a brownish hue. By means, therefore, of the aluminous mordant and the iron liquor, three very distinct colours, besides the black, are obtained from quercitron bark: and, moreover, by applying the aluminous mordant upon a madder red and an indigo blue, an orange in the first case, and a green in the second, will be produced when the piece comes to be dyed with the bark.

I have already noticed (at page 355 of Vol. I.) the practice of colouring the solution of alum, in the East Indies, with sampfan, or sappan, (red) wood; a practice which the calico printers of Europe have imitated, by colouring the aluminous mordant with Brasil wood, (and thence calling it *red* colour,) not only when it is intended to sérve as a basis for the madder red, but also for the quercitron or weld yellows; though in the latter case, at least, the practice ought to

be laid aside. It is, indeed, necessary that some tinge should be given to mordants in calico printing, in order that the printer may readily discern the exact progress and extent of his work: but it is much better to give this tinge, from quercitron bark, to figures, or parts intended afterwards to receive the bark or the weld colours by dyeing, than to give it from Brasil wood; the colour of which, were it to remain, would hurt the true yellow intended to be afterwards fixed upon the aluminous basis: but the false Brasil colour, not having so much affinity with the basis as to be able to maintain its situation, is always dislodged by the superior affinity of the bark or weld. This dislodgment, however, of one colouring matter by the application of another, takes up some time, and unnecessarily prolongs the dyeing process (the yellow in this case rising more slowly); and the parts intended to be kept white are also rendered liable to a greater degree of stain or discolouration. But where the mordant has been tinged with the quercitron bark, a portion of the colour intended to be given is already applied to the basis; and, though at first not perfectly fixed upon the linen or cotton, it soon becomes so in the dyeing vessel; whilst the additional colouring matter of the bark, having no false Brasil-wood colour to dislodge, applies itself without impediment to the aluminous basis, and produces the requisite

degree of colour much more quickly, as may be easily seen upon a proper trial.

I do not, indeed, think that any degree of tinge ought to be thus given, even from the bark, *beyond* what is necessary to enable the workman to see his work with sufficient clearness; because the particles of alumine or of iron, when previously united to any species of colouring matter, do not seem by cold application to fix themselves either so intimately or so *copiously* in the fibres of linen or cotton, as they do when applied without any such union or incumbrance; and I have repeatedly found, that yellow colouring matter, dyed upon an aluminous basis *untinged*, produced a more lasting colour than it does upon a basis previously tinged even by quercitron bark, and much more lasting than where the tinge had been given with Brasil wood. And this fact will enable us to conceive one, at least, of the reasons why it is most advantageous, in dyeing upon linen or cotton, to apply the aluminous basis first by itself alone. But, in topical dyeing with the quercitron bark, or with weld, wherever it is necessary to give a moderate degree of tinge to the mordant, whether aluminous or ferruginous, (i. e. iron liquor) or a mixture of these, I advise it to be given by a decoction of the bark made very strong, that it may not too much weaken the mordant, and at the same time employed as sparingly as the nature of the case will permit.

The effect of mordants topically applied, often depends greatly upon their being either too much or too little thickened with gum, starch, or flour, which are usually employed for this purpose. When the liquor has been too much thickened, it does not sufficiently penetrate the fibres or substance of the linen or cotton, and, therefore, the colour raised upon it proves weaker and less durable than it otherwise would do; but, on the contrary, if the liquor be not sufficiently thickened, it runs, or spreads, too far upon the surface of the piece, and produces figures, or impressions, which prove confused and undefined. In general, the liquor for this kind of application, should be made so thick, and only so thick, as barely to prevent its spreading beyond the proper limits; and it seems more necessary to catch exactly this point of thickness, or fluidity, with the iron liquor than with the aluminous mordant, because the oxyd of iron does not combine so intimately as the alumine does with the acetous acid; but, on the contrary, it remains suspended in a less divided state, and neither penetrates so freely, nor unites so intimately, as the particles of alumine with the linen or cotton to which it is applied; and, therefore, the iron liquor in particular ought never to be thickened any more than is necessary to hinder it from spreading too far.

When the mordant has been applied, and

has had sufficient time to penetrate the substance of the cloth, it should be thoroughly dried in air artificially heated, as before mentioned, so as to evaporate not only the water, but as much as possible of the acetous acid united to the alumine, or to the oxide of iron, in order that nothing may remain to oppose their intimate union with the fibres of the linen or cotton, which the water, and more especially the acid, necessarily would do by exerting their own particular affinities upon the substances intended to be thus intimately united. It will, however, be impossible in *this* way to evaporate the *sulphuric* acid, of which the aluminous mordant, made with the usual proportions of alum and sugar of lead, alway contains a little; and which, when the pieces are brought under the cleansing operation, enables the warm water to re-dissolve and separate a part of the alumine, wanted for raising and fixing the colours intended to be afterwards given by dyeing; which alumine, being so re-dissolved and separated, is apt, even in spite of the viscidity and entanglement of the cow-dung, to fix itself again upon those parts of the linen or cotton intended to remain white, and occasion a much greater and more lasting degree of stain, or discolouration, than would otherwise take place in the dyeing vessel. These effects might, indeed, be obviated, by mixing a little lime or chalk with the cow-dung and water employed

for the cleansing, so as to neutralise the sulphuric acid; but, by so doing, a sulphate of lime would be produced; and this, by fixing itself on the parts intended to be kept white, would give them a calcareous basis, and occasion another kind of stain, or discolouration, almost as bad as that intended to be thus prevented. But carbonate of pot-ash or of soda used in this way instead of lime, will answer the purpose of neutralizing the sulphuric acid, without communicating any improper basis of colour, so as to occasion that kind of stain or discolouration which it is so desirable to avoid; though if any more of it be used than what is sufficient barely to neutralize the acid in question, it will exert a mischievous action, by dissolving a portion of the aluminous basis fixed upon the linen or cotton, and render the yellow, afterwards communicated by dyeing, more feeble than it otherwise would have been. A *very little* of the mild alkali may, however, be used in this way with advantage, so as to leave the pieces capable of receiving full strong colours, whilst the parts intended to remain white will be but very slightly discoloured by the dyeing process, and afterwards easily whitened.

It is in all cases of great importance, that the cleansing operation should be well conducted, and thoroughly performed; but more especially where a large proportion of drab, dove, and olive, colours are to be intermixed with yellows;

because the oxide of iron, which serves as a basis to the former, is very apt to attach itself too copiously to the linens and cottons on which the iron liquor is printed; and unless the redundant part be carefully removed in the cleansing operation, (which is a work of some difficulty,) it will remain, and be afterwards attracted and separated by the colouring matter of the bark in the dyeing vessel; and, uniting therewith, it will give the dyeing liquor an olive or drab-colour tinge, and greatly tarnish the yellow figures, or designs, as well as stain the parts intended to be kept white: and, therefore, whenever the iron liquor is to be printed upon the same piece with the aluminous mordant, the former should be diluted as much as it will bear, without making the liquor too weak to afford a sufficient basis for the colour intended to be afterwards dyed upon it. By such dilution, joined to proper care in cleansing, the yellows may be made to come out of the dyeing liquor perfectly untarnished; which otherwise they will not do, at least when accompanied with any considerable proportion of figures, or designs, which have been printed with iron liquor.

Having premised thus much concerning the operations of printing and cleansing, I now proceed to that of dyeing with the quercitron bark. For this, a suitable portion of the bark, previously ground, is first to be put into a dyeing

pan, or vessel, with cold water, and the pieces to be dyed immediately after; a small fire is then to be lighted under the pan, so as gradually to warm the water; and, while this is doing, the pieces are to be slowly turned by the winch, in order that the colouring matter may apply itself equally: when the liquor becomes a little more than blood-warm, the colours will take sufficiently quick, and prove more lasting than they do when raised more hastily; because in a moderate warmth the colouring particles (as was before observed) have time, and are enabled to adjust themselves more accurately, and unite themselves more closely, to the particles of alumine, than they can do when hastily thrown and accumulated by a greater heat upon the printed figures or designs. And I have repeatedly found, that samples slowly dyed with the bark in this way, being exposed to the sun and air along with others dyed more expeditiously in a boiling heat, proved much the most lasting. And if the quercitron yellow has at any time been found less durable than that of the weld,* it can only

* Berthollet, in the last edition of his Elements, &c. has appropriated a chapter exclusively to the quercitron bark; which he begins with the following observation: "C'est a Bancroft que l' on doit l'acquisition de cette substance tinctoriale : il a donné une ample description de ses propriétés et des usages auxquels elle est propre : nous allons en presenter le sommaire;" &c. and after having done this, he adds "on doit indubitablement

have been so, through some defect in the mode of dyeing, at least if there was none in the mordant. Hitherto the bark has generally been used with too much heat *at first*. I say at *first*, because after the colour has been slowly raised, by liquor moderately warm, to nearly the proper height, a boiling heat will do no harm, excepting that of occasioning a little more stain or discolouration upon the parts intended to remain white; and though the avoiding of this is an additional motive for applying the bark in water of a moderate warmth only; yet this of it itself might not be a very powerful motive, because such stains from the bark are much more easily removed than those resulting from weld. But the most essential difference between these vegetables, respects the degree of heat by which their several colours are most permanently fixed upon linen or cotton; that of weld requiring

regarder le *quercitron* comme une substance tres utile en teinture ;" but after thus bearing testimony to its utility, he intimates a belief, that the colour which it affords is not so lasting as that of weld. But if there should be, as has sometimes appeared probable, some little foundation for such a belief, the difference is much more than compensated by the great advantage which the quercitron bark possesses of producing no discolouration to the grounds, or parts intended to remain white, sufficient to require a similar exposure on the grass by which the weld yellows always suffer, and are often greatly injured, particularly in winter, when the bleaching process is often necessarily continued several months.

at least a scalding, if not a boiling, heat to render it lasting, whilst the bark colour, as has been already observed, proves most durable when applied in water but little more than blood-warm. And, indeed, I have found, during the summer months, that cottons printed with the aluminous mordant were able to imbibe a good, though not a very high, yellow, by only remaining a few hours with bark in water of the heat of the open air, (in which it was placed,) and without any considerable stain or discolouration upon the parts not printed. A piece of the calico so dyed in the heat of the atmosphere only, being cut off and further dyed with the bark in boiling water, it imbibed a greater body of colour ; but a sample of this, and of the former or paler yellow, being equally exposed to the sun and air, I found at the end of three weeks, that the latter, which had been the deepest, retained no more body than the other ; the additional colouring matter, which in a boiling heat had been enabled to apply itself upon the aluminous basis, having been all discharged during this exposure to the weather. A fact which seems to indicate, that when the alumine has attracted to itself a certain portion of colouring matter, any addition made to it afterwards by the aid of heat, will be less permanently fixed, and, therefore, liable to be more speedily removed by any of the

causes which usually contribute to the decay of colours.

All the different shades of yellow may be obtained from the quercitron bark by varying the quantity, and applying it with greater or lesser degrees of heat during a longer or shorter time. By using the bark sparingly in water only blood-warm, pale delicate yellows may be raised in about fifteen or twenty minutes, and the parts intended to be kept white will receive scarcely any discolouration; by a larger proportion of bark, and by keeping the pieces for a longer time in the dyeing liquor, though without increasing its heat, a full and clear lively yellow may be produced; and by a still greater proportion of the bark, and a prolongation of the dyeing operation in a scalding heat during the latter part of it, the colour may be raised, first to a high golden, and afterwards to a very full brownish yellow. The quantity, therefore, of bark to be employed, must always depend upon the nature and closeness of the figures and impressions which are to be dyed, and the height or fulness of colours intended to be produced. Commonly, however, one or two pounds of bark will suffice for each piece; but, where too little has been employed at first, a farther quantity may be afterwards added without inconvenience; and, when the dyeing is to be performed in a very moderate heat, it will always be most advantageous to employ a

little more bark than is necessary; which may be done without any loss of colouring matter, because other pieces may be afterwards dyed, with a farther supply of bark, in the same liquor; and I have found that yellows, whether dyed from bark or weld, commonly prove most durable when the dyeing liquor has been somewhat plentifully stored with colouring matter; and, in general, I think it best to employ the bark so freely, as that the liquor may be strong enough, without being made more than blood-warm, to produce full bright yellows in the space of half or three quarters of an hour; the tinge, or discolouration, which the parts not printed imbibe from the bark in this way not being half so great as that produced by weld, and it being afterwards discharged with less than half the time and trouble which even an equal degree of stain from the latter would require. Indeed, where the pieces have been at first well cleansed from all loosely adhering and superfluous particles of the aluminous or ferruginous bases, the discolouration from bark generally proves so inconsiderable, that by rincing, or washing, them in cold, and more especially in warm water, it may be sufficiently removed without either branning or bleaching, excepting where the unprinted parts are required to be uncommonly clear and white: and when this is the case, I think it best to add after the rate of one pound of cream of tartar, in powder, for every twelve or fourteen pounds of bark, put-

ting the tartar into the water immediately after the bark, and then dyeing the pieces, as I have already explained. The tartar used in this way will contribute much towards keeping the white or unprinted parts free from stain or discolouration; and it will, moreover, give the quercitron yellow that bright, clean, and delicately greenish hue which is sought for in the weld, so as to make the former resemble the latter. But, as the tartar tends to keep the quercitron yellow from taking so fast, or rising so high, as it would otherwise do, the liquor may, in this case, be made hotter in the latter part of the operation. On the contrary, if, instead of tartar, one pound of clean white pot-ash be added for every thirty pounds of bark, a very high, and, at the same time, a very bright yellow will take so quickly, that the liquor should never be more than blood-warm: and, though the unprinted parts may seem a little more stained than they are when no potash is used, the stain will be discharged by thoroughly rincing and washing the pieces as usual.

Some calico printers, not acquainted with the best methods of employing the bark, have thought proper to join with it a little of the decoction of weld:* I cannot, however, recommend this practice, because, in truth, the bark, when properly used, wants no such assistance, and because the

* This practice seems no longer to exist.

colouring matter of the weld does not take permanently without a greater degree of heat than ought to be employed with the bark. It moreover occasions a much greater stain upon the unprinted parts, and at the same time degrades the madder reds and purples, (where these colours have been previously dyed,) much more than the bark.

It is to be observed, that the very moderate warmth, which best suits this kind of dyeing with the bark, does not, in general, completely extract its colouring matter, at least from such parts thereof as are not finely ground ; but, being tied up in a bag, it may be afterwards boiled separately in water, and the decoction so made may be employed for dyeing olive and drab colours, where they are not intermixed with yellows or reds. Some calico printers have, indeed, thought it best, in all cases, to begin by boiling the bark in a small quantity of water, so as fully to extract the colouring matter, and then, for yellow, as well as drab and other bark colours, to put a suitable proportion of the decoction into the dyeing vessel, with clean warm water, and dye the pieces therein, adding more of the decoction as wanted from time to time. I do not, however, think this practice so convenient as that which I have recommended.

A very ingenious printer in a distant country, and warm climate, some time since, favoured me

with an account of his method of using the bark, which he considers as one of the best: "I pound (says he) the bark, and boil it in a good quantity of water, say twenty-five gallons to seven pounds of bark; after which I let it settle, and pour off the clean decoction; of which I add a portion to a tub full of clean cold water, and immediately, with the hand, pass a quantity of clean rinced (printed) cloths through the water; they take on colour very quickly, and it appears fresh and beautiful: I then add another portion of the decoction, and bring out a pretty full yellow; meanwhile I have my large copper ready with clean water as warm as the hand can well bear, and to this I add also a portion of the decoction; and then remove the cloths from the tub into the copper, and turn them quickly round; by which method I obtain the best and most durable yellows: ten or fifteen minutes will be long enough to keep the cloths in warm water, where a delicate yellow is required." "I found it easy," continues the writer, "to manage the olive and drab colours in the copper; for *these*, I use the bark which has been once boiled for the yellow; seven or eight pounds of it are to be boiled in twenty-five gallons of water, and then the whole is to be thrown into a copper containing about 250 gallons; through which I pass about 225 yards of cloth perfectly well rinced, or, if it be heavy work, only about 180 yards, which are

to be turned quickly round: I begin with a moderate fire, which, in half an hour, is to be raised so as to make the water almost boil. Here, and especially for *dove* colours, I use a little sumach, which requires considerable heat before it produces any good effect; and, therefore, I think it useless for yellow, which the bark produces with so little heat. I have seldom allowed more than an hour for such olives, drabs, and doves; and I never join yellows with them, because the grounds will in this way be so much stained as to require more bleaching than the yellows can bear without injury; but doves, olives, and drabs, stand the bleaching, and remain unimpaired after the grounds are become perfectly white." This account the writer concludes by saying, "I have been able to do more variety of work with the bark than with any other colouring matter yet known; it is pleasing to work with, as it takes effect quickly, and is very easily managed by any person who knows the business of neutralizing salts, and preparing cloth to receive colour."

The rule which this gentleman seems to have prescribed to himself, of never joining the drab and dove colours to the yellow, is, I believe, much too rigid; for though, in truth, it is impossible to dye perfectly bright yellows where they are intermixed with any considerable proportion of what is called the *black colour*, and

difficult to do it where the drab and dove colours abound very much ; yet, in the latter case, this difficulty may be very much diminished by using the iron liquor of no greater strength than is necessary, and taking care to have the pieces thoroughly cleansed (as lately mentioned) before they are put into the dyeing vessel : if this be done, a considerable portion of olive, drab, and dove colours may be intermixed, and even a little of the black, without any material degradation of the yellow. To improve the black, and darken the drab or dove colours, (which the printer is often desirous of doing,) a little Malaga sumach, (*rhus coriara,*) in powder, may be advantageously employed with the bark, after the rate of one pound of the former to three or four of the latter. It is, I believe, generally thought best to raise the colours first with the bark, and afterwards change, or darken, the doves and blacks by adding the sumach, and continuing the process until the desired effects have been produced. My own experiments, however, lead me to conclude, that time may be saved, and every good purpose attained, with equal certainty, by putting the sumach into the dyeing vessel along with the bark, and thus applying the colouring matters of both at the same time; taking care, however, not to heat the dyeing liquor beyond what the hand can bear. In this way the parts unprinted may be kept perfectly white, so as

never to need either bleaching or branning. The sumach, indeed, when put into the water at the same time with the bark, and used in this way, produces, in an extraordinary degree, the effect of keeping the white or unprinted parts perfectly clear and free from all discolouration; which it probably does by means of a *particular acid*, contained in this and many other astringent vegetables: one pound of sumach to three of the bark will be amply sufficient for this last purpose; and in that proportion the sumach will make the parts printed with iron liquor incline towards a purple colour instead of the drab, which quercitron bark used *alone* would produce.

This change of colour produced by sumach will sometimes render the use of it inconvenient; but when this is not the case, a small proportion thereof joined to the bark, as before mentioned, will prove more effectual than cream of tartar in preventing even the slightest stain or discolouration upon the unprinted parts of cottons topically dyed.

A gentleman, of whose information I have more than once availed myself, some time since brought from Bengal, and gave me, a parcel of the dried leaves and tops of a plant there called *D'howah*, and employed, as he informed me, in the dyeing of topical or field colours, by putting a small quantity of it into the copper when the colours begin to rise, in order to keep the

grounds or unprinted parts clear; an effect which, upon trial, I found it produce nearly as well as sumach; and upon dyeing a bit of cotton, which had been printed with iron liquor and the aluminous mordant, separately, in a decoction of this plant only, it imbibed colours very nearly resembling those of sumach, though the decoction itself, even when made very strong, did not discover any astringency to the taste.

The berries of the common Pennsylvanian sumach *(rhus glabrum)* are covered with a red farinaceous matter, containing a large proportion of an acid, which appears to resemble that of tartar. These berries employed with the quercitron bark, after the rate of one pound of the former to twelve of the latter, produced effects nearly similar to those of cream of tartar, as already mentioned, in preserving the unprinted parts of cottons from being stained, and in giving the quercitron yellow the pale greenish complexion which distinguishes that of weld. Such means cannot, however, be employed where very full high yellows are wanted; and when this is the case, if the grounds or unprinted parts are required to be perfectly clear and white, it may be best to employ a little clean soda in the dyeing, as lately mentioned, and afterwards to spread the pieces for a day or two upon the grass, laying what is called the wrong side upwards, as is practised with other field colours. Those of madder and weld, indeed, always

require this operation, though it cannot be wanted for those of the bark, except in the single case just mentioned; and then only for a very short time, unless it be in rainy or cloudy weather, when this kind of bleaching proceeds very slowly with all colours, because the action of the air is then not only unassisted by the rays of the sun, but obstructed by the water which it holds in a state of solution,

Messrs. T. H. and son, very ingenious dyers of *printed* velverets, fustians, &c. near Manchester, some time since informed me of their having purchased the knowledge of an advantageous method of using the bark for this particular kind of dyeing, and of their having practised it with so much success as to have wholly laid aside the use of weld. This method they afterwards gave me an account of, in consequence of my offering to repay what it had cost them; which I did, from a desire to afford the public all possible information on this subject. Their account is as follows, *viz.*

"In using the quercitron bark, for every four pieces of half-ell velverets, about forty yards long, we take eight pounds of the light-coloured bark, and put it into a cask large enough to hold about 70 gallons, open at the top, and provided with a spigot and faucet, placed about six inches from the bottom, to draw off the liquor: we fill this cask with boiling water, stir it well, and let it remain upon the bark for three

hours or more; and then after the (printed) goods have been well washed out of the dyeing liquor, for the four pieces we put four pounds of Malaga sumach into a copper nearly filled with water, and with a very little fire under it; in this we put and keep the goods for about one hour, during which the dove or drab colours may be rendered sufficiently dark by keeping the liquor, at most, a little more than blood-warm. When the goods are taken out of the sumach liquor, they must be rinced in water; and whilst this is doing, we draw the clear bark liquor out of the cask, and put it into a copper with as much water as will serve to dye the goods conveniently; we then light a fire, and gradually bring the liquor to a blood warmth in about an hour, keeping the goods therein till the yellow becomes sufficiently dark or full, and taking care that the liquor be not made too hot. The goods, being well washed after dyeing in this way, will be found white without branning."

It ought to be remembered, that according to this method, the sumach is to be applied separately *before the bark,* instead of being applied *after* or *along with it*, as I have just recommended in calico printing. How far this method may be preferable to the other for the dyeing of printed velverets, future experience must determine; though, certainly, that of Messrs. H. and son ought, on this

point, to have great weight, even at present. In calico printing, however, this method of applying the sumach and bark has been tried, not only by the experiments which I have made upon a small scale, but by those which an ingenious calico printer made sometime since on a larger one, at my desire, and in both, without affording any reason to prefer it over the other.*

It can hardly be necessary for me to mention

* Some years after the preceding parts of this chapter were first published, and in consequence of M. Seguin's discovery, respecting the tanning principle in vegetables, it occurred to me to try the effect of gelatine, glue, or animal jelly, in separating and precipitating that principle, of which a large proportion notoriously existed in this, as well as other oak barks; and with this view I added a little of a solution of the whitest glue among that commonly sold, to the water, in which I dyed bits of calico, that had been impregnated with the aluminous and ferruginous mordants, and I have found, as I had, in some degree expected, that by this separation and precipitation of *tanning*, the yellow then dyed, was rendered more *delicately clean* and pure than it would otherwise have been, and that the *slight* discolouration of the white grounds, commonly observed, was, if not completely obviated, at least much diminished: since that time this use of glue has become general among the calico printers, and with so much benefit, in securing both the yellows and the white grounds, from the discolouration which, though slight, had before commonly resulted from the presence of the tanning principle, that *the use of weld in calico printing, has, as I am informed, been entirely laid aside for that of the quercitron bark,* at least in this kingdom.

here, that the quercitron yellow produces a green upon an indigo blue, and an orange upon the madder red, in the same ways, and by the same means, which enable the weld to produce these colours in calico printing. Nor need I

The following method of employing glue and sumach with quercitron bark, is extracted from a letter written by one calico printer to another.

"For dyeing the pieces, after they have been well cleansed, I recommend two pounds of the best glue, eight pounds of sumach, and eight pounds of bark, well ground, to be put together into a copper over night, if convenient; these quantities will sufficient for six of your heavy pieces. When the copper is made a little warm, the glue, if stirred, will soon disperse itself through the water, and produce its effect upon the colouring matters, and the parts which have been printed with the mordants, will speedily attract the dye; so that by proper management the grounds may be made *perfectly white*, only by washing the pieces when they come out of the copper; though you may pass them through hot water, if you think it necessary. When you have blacks and drabs to follow your yellows, the above proportions will be best; though they may be varied according to the nature of your work; e. g. you may employ to ten pounds of bark, to six or eight sumach. In all cases you may ground in the yellow on the table with the drabs, which will do away one fourth of the grounding, and you may bring all your yellows out of the copper, without any stain upon the grounds. Chintz work will not tinge the lay work; and this will be the case with olive and chocolate colours; and as they never need branning, or bleaching, the colours will not be impoverished by these operations; and the whole process may be finished in less time than is required merely to boil the weld."

mention the advantage which the bark possesses over weld in this way, by not tarnishing the madder colours upon pieces where such colours have been previously dyed; this advantage being now generally known and acknowledged.

Of the Uses of Quercitron Bark, in producing Topical *Yellow and other Colours,* prosubstantively, *upon Cotton and Linen.*

By the denomination of *prosubstantive* topical colours, I mean certain mixtures, in which the colouring matter and the mordant or basis are combined in a fluid state, fit to be applied *together* by the pencil, block, &c. to linen or cotton, as explained at page 358 of volume I; these are what calico printers have usually named *chemical colours*; an appellation too vague to be retained in a work which aims at precision and systematical arrangement.

Were it possible to obtain a sufficient number of *lasting* and *bright* colours of this kind, at a moderate expence, the art of calico printing might be practised with but little trouble, and would soon reach the highest degree of perfection. Whether so many of these ever will be discovered, as to render *topical dyeing* unnecessary, I know not; but if we cannot obtain all that is desirable in this respect, the art will, at least, derive benefit from any improvement in the few prosubstantive topical colours now in

use; and more especially from any addition to their number.

My readers already know that alumine, or the earth of alum, when dissolved, especially in the acetous acid, and conveyed into the pores of linen or cotton, is able afterwards *to attract to itself* different adjective colouring matters, applied either by general or by topical dyeing, so as to produce lasting red, yellow, and other colours; and it is much to be regretted that, for reasons which I have endeavoured to explain in other parts of this volume, the same mordant will not produce colours equally permanent, when it has been previously mixed with the colouring matter, and is afterwards applied (with it) topically to linen or cotton. The difference in this respect, is, indeed, very great among the madder colours; those dyed upon an aluminous basis, applied separately, being always very durable, whilst those given by prosubstantive topical application, (the colouring matter and mordant being first united) fade and decay very speedily. The difference is, however, so much less when colours are produced in these different ways from quercitron bark instead of madder, that I can with confidence recommend the bark, as affording better and more durable prosubstantive yellows for topical application, than any thing else yet discovered. The most simple yellow of this kind which I have to offer,

may be prepared in the following way and proportions, *viz*. For three gallons of prosubstantive tingent liquor, let three pounds of alum, and three ounces of clean chalk be first dissolved in a gallon of hot water, and then add two pounds of sugar of lead; stir this mixture occasionally during the space of twenty-four or thirty-six hours, then let it remain twelve hours at rest, and afterwards decant and preserve the clear liquor; this being done, pour so much more warm water upon the remaining sediment, as, after stirring and leaving the mixture to settle, will afford clear liquor enough to make, when mixed with the former, three quarts of this aluminous mordant, or acetite of alumine. Then take not less than six, nor more than eight, pounds of quercitron bark, properly ground, put this into a tinned copper vessel, with four or five gallons of clean soft water, and make it boil for the space of one hour at least, adding a little more water, if at any time the quantity of liquor should not be sufficient to cover the surface of the bark: the liquor having boiled sufficiently should be taken from the fire, and left undisturbed for half an hour, and then the clear decoction should be poured off through a fine sieve or canvas strainer. This being done, let six quarts more of clear water be poured upon the same bark, and made to boil ten or fifteen minutes, both having been

first well stirred; and being afterwards left a sufficient time to settle, the clean decoction may then be strained off, and put with the former into a shallow wide vessel to be evaporated by boiling, until what remains, being joined to the three quarts of aluminous mordant before mentioned, and to a sufficient quantity of gum or paste for thickening, will barely suffice to make three gallons of liquor in the whole. It will be proper, however, not to add the aluminous mordant until the decoction is so far cooled, as to be but little more than blood-warm, and these, being thoroughly mixed by stirring, may afterwards be thickened by the gum of Senegal, or by gum Arabic, if the mixture is intended for penciling; or by a paste made with starch or flour, if it be intended for printing.

Where gum is employed, it will be proper first to dissolve it in water, using only what is barely sufficient to produce a solution, lest a greater quantity of water should increase the mixture beyond the quantity of three gallons, for which the portions of bark and aluminous mordant here prescribed, will properly suffice, but not for more, without weakening the colour in some degree; and for this reason, it may be safest to evaporate the decoction rather more than seems necessary; because, when mixed with the other ingredients, if the whole proves

to be less than three gallons, the deficiency may be readily supplied by a little warm water.

In preparing this mixture, however, great care must be taken to thicken it only so much as may be necessary to keep it from running or spreading beyond the proper limits; since every degree of thickening, beyond this point, will hinder the colouring matter from penetrating sufficiently into the fibres of the linen or cotton, and thereby render the colour superficial and feeble.

When this prosubstantive mixture, (which I shall distinguish as No. 1,) after being duly prepared, has been applied to linen or cotton by the pencil, or otherwise, the pieces should be thoroughly dried by a stove heat, then soaked in lime-water, and afterwards streamed or placed in clean running water, to remove the superfluous colour; and if running water be wanting, other water should be copiously employed for this purpose, thickened with chalk and cow-dung.

A good lively yellow may be produced in this way, not indeed quite so lasting as that obtained when the mordant alone is applied first, and the colouring matter afterwards, by topical dyeing; it will, however, be able to bear the action of sun and air, and also of soap in washing, for so long a time, as almost to deserve the appellation of a *fast* colour.

It must, however, be observed, that this yellow, though nearly, or quite as high as that given by topical dyeing with either weld or quercitron bark, does not prove so high and full as is desirable for this mode of application; since colours which are applied by the pencil bear but a small proportion to the others with which they are intermixed, and are, therefore, required to be more *strikingly full*, that they may not be overlooked; and it is only in this respect that the colour obtained from French berries, (Rhamnus infectorius) and called the *berry* yellow, has given any degree of satisfaction, it being of all others the most fugitive and fallacious. To relieve calico printers from all temptation to use a colour, which, being fitted only to deceive, ought never to have been used, I have made frequent trials with the quercitron bark, joined to almost every possible mordant or basis; and of these, some have been attended with success, though the means employed in several of them, are either too expensive or too difficult of application for general use, by persons not versed in chemical operations. There are others, however, not liable to these objections; and, perhaps, all things considered, the most convenient among the several means of raising the quercitron yellow for prosubstantive topical application, and, at the same time, of increasing its durability, may be found in the nitrate of copper, and the nitrate of lime,

added to the mixture, No. 1, just described.* It is, indeed, true, that some of the solutions of tin produce still higher yellows with the quercitron bark; but they are liable to at least two objections, which will be particularly mentioned hereafter.

If copper, in small pieces, be put by a little at a time, into a large open glass vessel, partly filled with single aqua fortis, until the acid can dissolve no more of the metal; and if the solution be left open to a free access of air, it will soon be wholly converted into blue crystals, which are, what I mean at present, by the denomination of nitrate of copper. About one pound and a quarter of this salt may be added to the three gallons of prosubstantive yellow, No. 1, together with four ounces of pure unslacked lime, previously mixed with eight ounces of single aqua fortis. Clean oyster-shells, or marble thoroughly burnt, will afford the best lime for this purpose; which should be beaten into powder before it is put into the aqua fortis, to form the nitrate of lime here wanted. This, as well as the nitrate of copper, should be added to the

* A very cheap and useful composition of this kind may be made, by dissolving, in a *strong* decoction of the quercitron bark, a mixture of powdered alum, with half its weight of sulphate of copper, and one eighth of its weight of carbonate of soda—and afterward thickening the solution by gum, &c. as usual.

decoction of bark, before-mentioned, soon after the aluminous mordant, and before the liquor has been thickened, by gum or paste; and the mixture should afterwards be well stirred, and kept a little more than blood-warm for half an hour before the thickening is added.

The nitrates of copper and of lime, joined in this way to the mixture of No. 1, will considerably raise the yellow colour, and also enable it, for a longer time, to withstand the action of sun and air; they will also enable the colour to bear the action of vinegar and weak acids a little better than it otherwise would, though I do not consider this last as any test of the goodness of a colour, nor as being a circumstance of any great importance. This prosubstantive colour I shall distinguish as No. 2; and, considering that the bark in this way affords a colour full as high, and infinitely more lasting, as well as cheaper, than any which can be obtained from French berries, I think those calico printers, if there should be any, who may hereafter continue to employ the latter, will shew themselves strangely unmindful of their own interest, as well as of their duty to the public, and the credit of their art.

The nitrate of alumine, employed as a mordant with the decoction of bark, produces a prosubstantive topical yellow of considerable durability; but it is apt to acquire too much of a brownish complexion.

The muriate of alumine, mixed with the decoction of bark, produces in this way, effects very similar to those of common alum; and this is also the case where a tartrite of alumine is employed. Alumine dissolved in the pyro-ligneous acid, being tried with the bark in this way, produced effects perhaps a little, though but a very little, better.

None of the solutions of alumine by potash, soda, or ammonia, succeeded as mordants with the bark, for topical application, so well as the solutions made by acids.

If a decoction be made from six or eight pounds of bark, as directed for the preparation No. 1, but without any of the aluminous mordant, and if two pounds of the nitrate of copper, lately described, be dissolved therein whilst a little warm, and the mixture afterwards properly thickened, it will produce, when applied to linen or cotton, a good prosubstantive *yellowish green*, capable of bearing exposure to sun and air, and washing with soap, so as almost to deserve the name of a fast colour. By adding four ounces of lime, mixed with eight ounces of aqua fortis, the colour will be improved; and it may be rendered still more beautiful, and, I think, a little more lasting, by adding immediately after the nitrate of copper, one pound of ammoniate of copper, made by pouring a pound of the liquor ammoniæ, of the London

Dispensatory, into a close glass vessel, with a sufficient quantity of filings, or small bits, of copper, and keeping the vessel closely stopped, until the alkali has combined with as much copper as it can dissolve, and thus acquired a very beautiful deep blue colour. This yellowish green prosubstantive mixture I shall distinguish as No. 3; and, I believe, there are no other means by which a similar colour can be obtained of equal beauty and durability.

The ammoniate of copper alone produces, with the decoction of bark in this way, a greenish yellow deserving of notice.

The acetite of copper (verdigrise dissolved by vinegar) mixed with a decoction of the bark, and topically applied upon cotton, producès a full brownish yellow, which, however, proves not so lasting as either No. 1, or No. 2.

And the muriate of copper, with the decoction of bark, produces in this way a yellowish olive, which soon fades upon linen and cotton.

It has already been noticed, that cottons impregnated with the oxides or solutions of tin as a basis of colour, and then dyed with quercitron bark, imbibed colours highly beautiful, and capable of resisting the action of boiling soap-suds, as well as of strong acids; but, at the same time, fugitive when exposed to the sun and open air, a defect which it would have been reasonable to expect, even in a greater

degree, where the tin basis, instead of being previously fixed in the cotton, was first united to the colouring matter, and afterwards applied therewith prosubstantively. A contrary effect, however, really takes place, in some degree, because the oxide of tin has greater affinity to the fibres of cotton, after a previous combination with the colouring matter, than it has separately.

If a decoction be made from six pounds of bark, as for the preparation, No. 1, (but without any aluminous mordant), and one pound, or one pound and a quarter, of the murio-sulphate of tin, so often mentioned, be added, the mixture being afterwards well stirred, and properly thickened, will afford a very bright and full prosubstantive yellow, liable, indeed, to become a little brown by exposure to the sun and air; but, at the same time, of considerable durability, and able to withstand the action of acids or boiling soap-suds. It must, however, be remembered, that the oxide of tin has a stronger attraction than that of iron, for most vegetable colouring matters, and especially for that of madder; and, therefore, when prosubstantive colouring mixtures, containing solutions of tin, like that just mentioned, are applied *closely* upon madder purples, or blacks, (made such by the oxide of iron) these latter colours will become red wherever they are touched by these mix-

tures. And for this reason, whenever a prosubstantive yellow is wanted to be laid immediately upon the edge of a dark madder colour, (which is most frequently the case) it will be proper to employ the preparation, No. 2.

The nitro-muriate of tin, made with about two parts of nitric to one of muriatic acid, produces, in this way, with the decoction of bark, a very high lively yellow, capable of resisting strong acids, boiling soap, &c. but very liable to become brown by exposure to the sun and air; an effect which I found lemon juice had the power of preventing, in spots, which, for another purpose, had been wetted therewith. Olive oil, applied so as to cover yellow spots or figures produced by the decoction of bark and nitro-muriate of tin, appeared to have no effect in defending or preserving the colour from injury by exposure to the sun and air; and linseed oil, applied in the same way, did manifest harm, the spots covered by it having acquired a blackish hue after a few weeks exposure to the weather. These, joined to other facts, may hereafter help us to some useful conclusions. Muriate of tin, with the decoction of bark, applied prosubstantively to cotton, affords a very lively delicate yellow; but it is less capable than the former of resisting the action of soap and of acids; nor does it long bear exposure to sun and air. This is also true of the yellow produced in

this way by the tartrite of tin and decoction of bark

The sulphate of tin, mixed with a decoction of the bark, and applied in this way to cotton, gives a kind of cinnamon colour sufficiently lasting. Phosphate of tin produced only a dull brownish yellow with the decoction of bark. Tin, dissolved by cream of tartar, mixed with twice its weight of muriatic acid, produced, with a decoction of the bark, prosubstantively upon cotton, a very lively strong yellow, of considerable durability. I have tried many other solutions and combinations of tin with the bark, and, indeed, almost every one which it is possible to form, but without any effects better than those which may be obtained from the mixtures already mentioned. My readers, therefore, will not require a particular account of them, especially as the use of all prosubstantive yellows which contain solutions of tin, though they afford by much the highest and most beautiful colours, must prove very limited, by reason of their effect of reddening the dark madder colours.

It has been already observed, that the decoction of bark with the nitrates of copper and lime, and the ammoniate of copper, produces a good prosubstantive yellowish green; and this may be rendered darker and fuller by superadding a portion of the logwood blue. Two calico

printers have assured me, that by combining the bark and logwood with particular solutions or preparations of copper, they had been able to obtain a green, for topical application, so fast as to bear the process of field bleaching without injury; and one of them declared, that it was by adding to a decoction of bark and logwood, boiled together, a suitable portion of sulphate of copper and of verdigrise, with a little potash; this last, and the effervescence which is produced, he seemed to think of importance. As yet, however, my endeavours to produce a green fully answering this description have not succeeded, though they have several times been attended with such appearances of success, as will induce me to make farther trials. Those hitherto made seemed to have failed principally by the want of sufficient permanency in the blue or logwood part of the green colour. A great number of experiments, made at least seventeen years ago, taught me, that a beautiful prosubstantive blue, capable of resisting sun and air for a considerable time, when applied topically upon linen or cotton, might be obtained by combining the colouring matter of logwood with the sulphate of copper and the ammoniate of copper; a fact which I communicated to several calico printers, who have acknowledged its beneficial effects.

Six pounds of logwood boiled with water, as directed for the quercitron bark, will afford co-

louring matter enough for three gallons of liquor when thickened; to this decoction, whilst warm and before it is thickened, two pounds of blue vitrol may be added, and as soon as it is dissolved, two pounds of ammoniate of copper, made as already explained, and the liquor, after being well stirred, may be thickened and applied as usual. By substituting the nitrate of copper for the sulphate of that metal, a dark blue may be produced, equally durable, but not so lively and beautiful; though I think this last rather preferable to the other, for the purpose of forming a prosubstantive green with the quercitron yellow; for which purpose it will be sufficient to mix as much of this logwood blue with the yellowish green, No. 3, as may serve to produce the particular shade of colour wanted; or the logwood blue may be added to the yellow, No. 2, for the like purpose. And though the greens produced in these ways are not so lasting as to deserve to be called fast colours, they are as good as any which I have yet been able to produce by uniting the quercitron and logwood colouring matters, and, indeed, are such as it may be often convenient to employ.

If a suitable portion of strong iron liquor be mixed with a decoction of the quercitron bark, made as already directed, and the mixture be properly thickened, a prosubstantive drab colour of some durability for topical application, may

be produced; and this mixed with an equal portion of the preparations, No. 1, or No. 2, will produce an olive. If a solution of iron, by a diluted muriatic acid, or by a diluted nitric acid, be employed for this purpose instead of iron liquor, it will produce colours a little more lasting; but these solutions should be employed sparingly, that they may not hurt the texture of the linen or cotton to which they are intended to be applied.

Zinc, dissolved by the sulphuric, the nitric, and the muriatic acids, separately, and mixed with the decoction of bark, produces brownish yellow colours of different shades, but none of them sufficiently lasting when topically applied upon linen or cotton.

Mercury, dissolved by the different acids, produced with the decoctions of the bark different brown and yellowish brown colours, but none of them more durable in this way, than those afforded by different solutions of zinc.

The nitro-muriate of platina, mixed with a suitable portion of decoction of bark, and topically applied either to linen or cotton, produces strong full-bodied snuff colours, which bear the action of acids and of the sun and air.

The nitrate of silver, mixed with a decoction of the bark, produces, by topical application upon linen or cotton, strong dark brown and cinnamon colours of considerable durability.

The nitrate of lead, with the colouring matter of bark, produces in this way a drab colour of equal durability.

The nitrate of bismuth, with a decoction of the bark, produces a very full and strong brownish yellow, which would prove lasting, were it not liable to become almost black by alkaline sulphures, by sulphurated hydrogenous gas, and sometimes by the action even of common soap.

The muriate of bismuth produces a drab colour with the bark, and the sulphate of that metal a yellow; but neither of these are lasting upon linen or cotton.

The nitro-muriate of antimony produces with the bark, a kind of snuff colour of some durability on linen and cotton; and different shades of brown were produced in this way by the nitrate and the muriate of cobalt with the bark, which, however, soon faded by exposure to sun and air.

In giving this account of the properties and uses of quercitron bark, I have had before me notes of several thousands of experiments made therewith, in almost all possible ways, and with almost all possible chemical agents. But as a detail of their effects would more than exhaust the patience of any reader, I shall content myself with stating, as I have here done, the results of those which seem most likely to prove useful; and, probably, what I have already stated is more than enough on this subject. I have,

however, thought it incumbent on me to omit nothing in any degree likely to afford useful information respecting a *new dyeing drug*, first brought into use by my exertions, and which, without them, would, probably, have remained unknown as a dyeing drug for ages to come:— a drug which has already produced important benefits, especially to the art of calico-printing in Great Britain; and is likely hereafter to benefit other European nations, as well as the United States of America, in an eminent degree. The consumption has, indeed, hitherto been small, compared to the probable future increase; but it has been large, considering the short time since its properties were first made known, and the immense difficulties which attend the introduction of all new dyeing drugs: it appearing, by the act of the 13th and 14th of Charles II. ch. 2, that nearly one hundred years had elapsed before "the ingenious industry of modern times had taught the dyers of England the art of fixing the colours made of logwood." And though indigo, the most valuable of all dyeing drugs, had been known in Asia for at least two thousand years, the use of it was either prohibited or restrained for a considerable time in different European countries, from an erroneous belief that its colour was fugitive: so difficult has it always been found to bring dyeing drugs into their *due estimation*. But though the quercitron bark has been

employed only for so short a time, I flatter myself that the account which I now offer of its properties and uses, will prove much more complete than any yet given of the properties and uses of any other dyeing drug, even among those which have been known for many ages. Had I done less I might well have escaped blame, "for (to use the words of Sir John Sinclair) no individual, or even *nation*, can carry any art or new invention to its ultimate state of perfection. It must be improved upon for that purpose, by the investigation and experience of others." See his "Plan of agreement among the powers of Europe, &c. for the purpose of rewarding discoveries of general benefit to society."

ARTICLE II. Of the juglans alba, or *American hiccory*. Not only the bark but the green leaves and the rinds of the nuts of this tree, yield an adjective colouring matter so very similar to that of the quercitron bark, that all the instructions which I have given respecting the latter, will be found applicable to the hiccory; allowing only for the difference between their respective proportions of colouring matter; that of the hiccory bark being about one-third less than what is contained in a like quantity of quercitron bark. It is this difference, joined to the greater difficulty and expence of grinding the hiccory bark, it being very hard and tough, which has enabled the quercitron bark almost wholly to

supersede the use of the hiccory; for, excepting the prosubstantive topical yellows, for which it does not seem to answer quite so well, there is, perhaps, no purpose to which the colouring matter of the hiccory may not be applied with effects as good as those resulting from the quercitron bark; and I have sometimes thought, that some of the *varieties* of this tree might be preferable to the quercitron bark, for imitating the greenish lemon yellow of the weld plant on wool, with an aluminous basis. I say of some of the *varieties*, because there certainly are considerable differences between the shades of yellow produced by the several varieties of the hiccory tree; that, for instance, which Marshall calls juglans alba accuminata, produces a clear lemon yellow, whilst the juglans alba minima produces a fuller, though not a very bright, yellow; and the juglans alba odorate, a yellow which is very full and also very lively.

Generally, however, the hiccory bark employed in the way of calico printing, or topical dyeing upon linen and cotton, produces colours very similar to those of the quercitron bark, both upon the aluminous and ferruginous bases, and with no greater degree of stain or discolouration upon the parts intended to be kept white. This also is one of the vegetable colouring matters, of which the use was exclusively secured to me for a term of years by act of parliament.

CHAP. III.

Of Madder—Rubia Tinctorum, Rubia Peregrina, and Rubia Manjit'h.

> "Crescit profecto apud me certe, tractatu ipso admiratio antiqui-
> "tatis: quantoque major copia herbarum dicenda restat, tanto ma-
> "gis adorare priscorum in inveniendo curam, in tradendo benigni-
> "tatem subit."
>
> C. Plinii *secundi Histor. lib.* xxvii. *cap.* i.

The genus *Rubia* is of the *natural* order of *stellatæ*,* which, more than any other, abounds in roots affording the *red* colouring matter. It contains seven species, which have been accurately described; though but three of these appear to have been employed by the dyers of Europe, viz. 1st. Rubia tinctorum, Lin. or rubia tinctor, sativa, of Bauhin, (Pinax. 333) with annual leaves, a prickly stem, and perennial root. This is properly the *Zealand* madder, and appears to have been greatly cultivated in that province, during more than 300 years; the Emperor Charles the Fifth, having encouraged its cultivation, by particular privileges conferred on the inhabitants of Zuyderzee, for that purpose; and Great Britain

* i. e. Having their leaves set round the joints of the stem, in the form of a *star*.

alone is supposed for a long time to have paid annually two millions of guilders (nearly £200,000 sterling) for the purchase of Zealand madder;* which is, I believe, never exported otherwise

* Berthollet appears to think it uncertain whether the madder of the ancients was similar to ours; though I cannot discover any sufficient reason to doubt of its having been one of the species now employed by the dyers in Europe. It is, indeed, true, that in regard to this, as well as most other productions, the descriptions left by the Greeks and Romans are not so pointed and characteristic as they ought to have been; but as far as they extend in this instance, they accord very well with the common dyer's madder. Dioscorides, under the name which it bore among the Greeks of Ερευθοδανον, (Eruthodanon), describes its long square stem as being armed with hooks, and its leaves as being placed in the form of a *star* around the joints; and after mentioning the colour of the fruit, as changing from green to red, and, finally, to black, he adds, that its long slender roots are *red* and serve for *dyeing*; and that, for this purpose, they are cultivated with great profit in Galilea, and about Ravenna, in Italy, as well as in Caria, &c. (see lib. iii. cap. 160.) The description of Theophrastus (Hist. Plant. ix. c. 24) agrees very well with this by Dioscorides: Pliny mentions madder, with its use for dyeing wool, &c. in three several places, under the name which it now bears, of *rubia*, adding its Greek name; in one of them (i. e. lib. xxiv. cap. 11.) and in lib. xix. cap. 3. he says, "it grew both wild and by cultivation, from slips; and that the madder of Italy was most esteemed, especially that which grew around the villages near Rome;" he then compares it to a species of *vetch* (ervilia) and adds, that it had a prickly stalk with joints, surrounded each by *five* leaves spreading in form of an *orb* or *star*. "Verum spinosis ei caulis: geniculatus hic est, quinis circa articulos in orbe foliis."

than in a prepared state. To bring madder into this state of preparation, the roots, after being extracted from the earth, freed in some degree from the dust, and dried by a stove heat, are placed upon concave oaken blocks, each having six stampers plated at the bottom with iron bands, which (stampers) are moved or worked by horses with suitable machinery. The first pounding separates and brings into the form of a powder the very small roots, with the skin or husk of the larger ones, and any earth which may have been left adhering thereto ; and this powder being sifted, is packed separately in casks, and sold at a low price under the name of mor *mull* ; but is commonly known in this country, only by the latter of these names, and employed exclusively for cheap dark colours. A second pounding separates about one-third of the remaining part of the larger roots, and this being sifted and packed separately, is denominated gort *gemeen*, ordinary powder, (of madder) and sold here under the name of *gemeen* or gemeens. The third and last pounding comprehends the residue, or *interior*, *pure*, and *bright* part of the roots, which, according to Mr. Miller, is packed under the name of "*kor kraps* ;" but in this country, it is simply called *crop* madder.* Some-

* The *mull* is called "garance *courte*" by the French—the gemeen, "garance *mi-robée* ;" and the crop, "garance *robée*"— and also "garance *grappe*."

times, after the *mull* has been separated, all the remaining part is ground, sifted, and packed together, under the name of onberoofde, which consists of about one-third of the gemeen, and two-thirds of the crop. In Zealand the madder is dried by a very moderate heat; and the last pounding is chiefly performed by night; day-light being thought to detract from the brightness of the colour. Crop madder, if exposed to a damp atmosphere, attracts moisture, and is soon greatly injured by it.

If the roots of madder be examined with a magnifying glass, the interior part will be found to contain a considerable proportion of specks or particles of a *bright red* colour, intermixed, or in contact with a kind of ligneous substance, which, as well as the cortical part, seems, unfortunately, to abound with a sort of brownish yellow colouring matter, called *fauve* by the French; and this contributes to degrade the *fine red,* which madder would otherwise afford; though the degradation may, in some degree, be obviated or diminished by extracting the colouring matter in water, which is but moderately warm; the brownish yellow tingent matter not being soluble so readily, and in so great a proportion as the other, so long as the heat of the menstruum is below the boiling point. There is, also, another difference, which is, that the brownish yellow tingent matter, does not attach itself so permanently as the *red,* to the aluminous basis;

and of this the dyers of the Turkey red avail themselves, by separating and discharging the former from the latter, after both have been applyed or dyed upon the cotton yarn, &c.; employing, for this separation, a solution of soap with water heated often above the boiling point; and thus obtaining a colour equal in beauty to any which cochineal would produce upon a *similar basis.* But this method of *purifying* the madder colour, by an abstraction of the brownish yellow part, cannot be employed upon wool, which at a degree of *heat so elevated*, would be greatly injured by soap.

Water of the ordinary temperature of the atmosphere, may be made to dissolve and extract nearly all the red colouring matter from madder; but to do this, it must be copiously employed; and the colour will be more beautiful when the extraction is performed by cold, than if performed by hot water: alkalies increase the solvent power of water, and especially in regard to the brownish yellow (or fauve) part of its colouring matter; whilst acids weaken or reduce the red part, if allowed to act upon it when *un*supported by an aluminous or other basis; water is capable of dissolving a larger proportion of the brownish than of the *red* tingent madder; but for this purpose it requires a greater degree of heat.

Bartholdi asserts, that the roots of madder,

contain a large proportion of sulphate of magnesia; and Braconnot found in them a very considerable quantity of potash, neutralized by the malic acid. See Ann. de Chimie for June, 1809. D'Ambournay, and some others, have pretended that the roots of madder might be most advantageously and economically employed when fresh gathered; but this pretence is contradicted by the general experience of dyers, who find that, if properly dried, and afterwards carefully secluded from moisture, they will improve by being kept one or two years, even in powder.

Of the Application of Madder to Wool and Woollen Cloth.

Though the red colour dyed from madder, upon wool impregnated with the *aluminous* basis, is less bright and beautiful than that of cochineal, it has the advantage of being cheaper and more durable; and for these reasons it is greatly employed, especially upon the cloth worn by British soldiers: of the application of this basis (with tartar) upon wool and cloth, as a preparation for this and other extractive colouring matters, I have already given a sufficient account, at, and between pages 384 and 390 of my first volume; and though Scheffer has directed a much larger proportion of tartar to be employed in this preparation, I am confident that he has done

so without reason, and that no advantage would result from such an augmentation of it. Wool or cloth being prepared, as described at the pages just mentioned, and good crop madder, at the rate of from four to eight ounces for every pound of wool or cloth to be dyed (according to the quality of the madder, and fulness of colour required) being put into a suitable quantity of water in the dyeing pan, and the water being gradually warmed, until it has become almost as hot as the hand can well bear, the prepared and moistened wool or cloth is to be dyed therein, by the usual management, taking care not to employ more than a scalding heat, until the colouring matter has been sufficiently applied; after which, it is commonly thought expedient, (in order more effectually to *fix* the colour) to make the liquor boil a few minutes, before the wool or cloth is taken out of it. In large dye houses, more than 600lbs. in weight of cloth, is frequently dyed with madder at a *single* operation; and when this is finished, and the red part of the madder colour taken up by the cloth, the liquor appears to be highly charged with the remaining yellow part, which, not having so much affinity as the red for the aluminous basis, is not taken up by it in an equal proportion, so long, at least, as the heat continues below the boiling point.

Whether the colour be in reality fixed more permanently by *boiling* the dyed cloths a few

minutes, as is commonly practised at the conclusion of the operation, is a question which I am afraid to answer, as the results of several trials which I have made were not uniform; but if it should be found expedient to employ a *boiling* heat for this purpose, all danger of any harm from it might be avoided, by giving it with *clean* water, in a separate pan, to which the cloths might be removed, after having already imbibed sufficient colour, with only a scalding heat; in this way there would be no danger of increasing the extraction of the yellowish brown colouring matter, or promoting its application either to the cloth or the aluminous basis.

When it is thought desirable to render the madder red brighter than it can be made by alum and tartar only, (as mordants) some dyers are accustomed to add a small proportion of nitro-muriate of tin to the other mordants, in *preparing* the cloth. But a more beneficial effect would be produced by reserving this nitro-muriate, and employing it with the madder (putting both into the water at the same time) for the dyeing operation; because, the acids, combined with the tin, will, in a considerable degree, obstruct the extraction of the yellowish brown part of the colouring matter; and a similar effect may be produced by employing a little sour bran liquor along with the madder. Sometimes orchall and Brasil wood are combined with madder, to render

its colours more *rosy*; but their effects are not lasting.

Having witnessed the utility of glue, in purifying and brightening the colours of morus tinctoria, and quercitron bark, I tried it with madder, though unsuccessfully; the latter appearing to be destitute of *tannin*, or any matter capable of being separated or precipitated by an animal jelly.

In regard to the application of tin, or rather the solutions of that metal, as a *basis* for the madder red upon wool, I think myself warranted, by numerous experiments, to recommend it, where colours approaching the scarlet from cochineal are wanted, though I do this in opposition to the high authority of MM. Berthollet, (father and son) who assert, that their multiplied experiments with this mordant have not produced any beneficial effect worthy of notice, in regard to the madder colour, (see Elements, &c. tom. ii. p. 122 and 125;) and I can only account for this assertion, so much at variance with my own ample experience, by supposing, that in all their trials with madder, the nitro-muriate of tin was exclusively employed, (as it has been by the dyers) to *prepare* the cloth, and wholly omitted in the second or *dyeing* operation with madder; and certainly when so employed, the colour will be but little brightened or improved; though, if a part of this nitro-muriate be reserved and mixed with the water, before the madder is put into it,

so that its acidity may obstruct the extraction of the yellowish brown part of the madder colour, a very sensible increase of its vivacity will soon become evident : or, even if the whole of the solution of tin be employed to *prepare* the cloth, a similar effect may be obtained, by mixing a portion of tartar conjointly with madder in the dyeing vessel, as the tartaric acid will be equally efficacious with the nitro-muriatic for impeding the extraction of the brownish yellow part of the madder colour. And the effect of the little thereof which may be extracted and taken up by the cloth, might be nearly overcome, by adding a very small portion of cochineal to the madder. Sour bran liquor will operate in the same way as tartaric acid, but neither should be employed in excess, least it should reduce or weaken the red colour. Cloth prepared with a solution of tin and tartar should not be rinced previously to their being dyed, unless the solution has been used to excess.

I have already mentioned (at p. 495 of my first volume) that the madder colour, when dyed upon the basis of tin, had been found, in my experiments, to be extremely durable; and when properly dyed, it certainly is but little inferior in vivacity to that of cochineal, and might, perhaps, be made even to surpass the latter, if the *pure red* part of the root could be *exclusively* applied with the oxide or solution of tin; or if, after being applied conjointly with the brownish yellow

part, this last could be separated from the former, by the means employed to purify and enliven the Turkey red, or by any other means which would not injure either the cloth or the colour. For as the Turkey red, though dyed upon the aluminous basis, is, by this purification or separation, rendered nearly equal in vivacity and beauty to the finest cochineal scarlet, which has been dyed on a basis derived from tin, there is reason to conclude, that by a substitution of the latter basis, a colour more excellent even than the best scarlet might be produced with such purification. But, unfortunately, this substitution is impracticable upon either linen or cotton, because there is but little affinity between either of them and the oxide of tin ; and when the substitution is made in regard to *wool*, the means by which the madder colour is afterwards purified on *cotton*, cannot (as was lately observed) be employed upon wool, without destroying it.

Such is the affinity of madder for wool, that when both are put into water and kept at a scalding heat for one hour, the wool will imbibe a full, though brownish red colour; and broadcloth boiled for half an hour in water moderately acidulated by sulphuric acid, and afterwards dyed, unrinced, with madder, will acquire a better red ; which, though less bright and less permanent than that dyed upon the *aluminous* basis, will bear exposure to the sun and air, during two months, with-

out any considerable injury. Cloth treated in the same way with water acidulated by the nitric, muriatic, tartaric, and citric acids, and dyed with madder, took reds of different shades, but of nearly equal permanency. *These effects were to me very unexpected.* Linen and cotton, however, took no colour by the same treatment and means. A strong proof of the greater affinity of some colouring matters for animal than for vegetable substances.

The remarkable effect of madder, in giving its red colour to the bones, but not to the soft parts of animals, with whose food it had been mixed,* appeared to indicate a considerable attrac-

* Beckman, in his history of inventions (vol. iii.) mentions Lemnius, (a Physician in Zealand, where madder had been long cultivated) as being the first writer who had published this fact, and he quotes the following words from the treatise of Lemnius de Miraculis occultis naturæ, printed at Cologne, in 1581, viz. "Erythrodanum seu rubea ossa pecudum sandicino rubentique colore imbuit, si quando herbam virentem depasta sunt, intacta etiam radice, quæ rutila existet; quod etiam in elixis decoctisque; ejús pecoris carnibus perspici potest, et in ovis, quæ rubicunde colore radicis decocto fucantur." Beckman acknowledges, indeed, that this passage does not occur in the first edition of the work, printed in 8vo. in the year 1559, but supposes it to have been contained in the second, which was printed in 1564; and that a knowledge of this fact was thus obtained by Mizaldus, who, in his "Centuriæ novem memorabilium, utilium ac jucundorum," printed in 8vo. at Paris, in 1566, states the same fact in *almost the same words.*

It will have been seen in the passage just quoted, that Lemnius

tion between calcareous earth and the colouring matter of this root, and I was induced by it to employ the former as a basis for the latter, in dyeing both upon wool and cotton; but the effect did not answer my expectation; as neither lime recently burnt, nor the carbonate of it, when mixed with madder in water, produced colours more lively and permanent than madder alone. But broadcloth, boiled in water with lime and sulphuric acid, in such proportions as to neutra-

mentions this effect upon the bones of animals, as having been produced by their feeding only on the *leaves* without the *roots* of madder; and Beckman says he has proved in his "Experimenta emendandi Rubiæ usum tinctorum," that the *green leaves* of madder contain, and really communicate, a *red dye.*

Though this effect of madder upon the bones of animals had been thus mentioned in the 16th century, by Lemnius and Mizaldus, it was forgotten and become unknown, until the late Mr. John Belcher (a surgeon) happened to dine with a calico printer in Surrey, about the year 1736, and observed that the bones of some pork which made a part of the dinner, were red; when, upon expressing his surprise at the fact, he was told, that the hog from which it was taken, had been fed on bran, after it had been employed in one of the operations of calico printing, and had thereby imbibed the colouring matter of madder roots. Mr. Belcher afterwards ascertained, by adding some powder of madder roots to the food of dunghill fowls, that a similar redness was thereby communicated to their bones; and he gave accounts of his observations and experiments to the Royal Society, which were printed in the Phil. Trans. No. 442, and No. 443, (1736), and these were followed by others from M. du Hamel du Monceau, in 1740.

lize the latter, and afterwards dyed with madder, took a lasting red colour, though not so bright as when dyed upon the aluminous basis. Cotton, however, being treated in the same manner, was but slightly discoloured.

Broadcloth, prepared with a nitrate of lime, and dyed with madder, took an orange colour; but cotton treated in the same way, remained almost white. Muriate of lime with madder, produced a brownish red, upon wool which suffered but little by thirty-eight days exposure to the sun and air.

Broadcloth, prepared with sulphate of magnesia, and dyed with madder, took a salmon colour of but little durability. Cotton treated in the same way, remained nearly white.

Broadcloth, boiled with muriate of barytes, and afterwards dyed with madder, took a dull red, of but little durability.

Broadcloth, boiled with muriate of antimony, and dyed (unrinced) with madder, took a very good and permanent red; less bright, indeed, than that dyed with solutions of tin, but preferable to that commonly dyed upon the aluminous basis.

Broadcloth, treated in the same way with nitro-muriate of cobalt and madder, obtained a reddish brown colour; with nitrate of bismuth and madder, a dark brownish red; with nitro-muriate of zinc, a reddish orange colour; with nitrate of lead, an orange, inclining to the

brick colour; and with sulphate, nitrate, and muriate of copper, separately, browns, inclining more or less to yellow.

Iron, dissolved by the sulphuric, nitric, and muriatic acids, and applied severally as a basis to cloth, produced with madder various shades of dark coffee colours, somewhat approaching the violet.

Silk, macerated during twenty-four hours in a diluted muriate, or nitro-muriate of tin, not more than blood-warm, and afterwards dyed, unrinced, with madder in water moderately warm, acquired a lasting red of considerable vivacity; and being macerated in a cold solution of alum, instead of the solution of tin, it obtained, in the same way, from madder, a permanent red, similar to that commonly dyed by the same means on wool or cloth; but as the most lively and beautiful colours are generally required for silk, those of madder are but rarely employed with this substance.

On *Linen* and *Cotton*, the madder colour is eminently useful with the basis of alum; and for dark colours, with that of iron; which, indeed, are the only bases employed in calico printing, as was observed in my first volume; where, (i. e. between pages 358 and 378) I have described the preparation of the acetate of alumine and that of iron, as well as the means and methods of applying them to calico intended to be printed; and I have, moreover, given a concise account of the manner in which the

calico, when printed, and afterwards cleansed, is to be dyed with madder; but of this last operation, it may be proper that I should furnish some additional explanations.

Calico, when intended to be printed and dyed with madder, should be first carefully and thoroughly bleached; and even when this has been done, it should be immersed for some time in an alkaline lixivium of proper strength, and (after being rinced) macerated a few hours in water acidulated by sulphuric acid, to dissolve and remove any earthy matters which might otherwise, not only degrade the madder red, but fix it on the parts intended to be kept white.

The proportion of madder to be employed must depend upon the extent of surface intended to be coloured by it, and the depth or fulness of the colours desired: when very full dark reds are to be produced, it will be best to employ but *half* of the madder at *once*, and repeat the operation with the other half, in order to avoid that alteration and degradation, which the madder colour suffers, when kept longer than usual, even at a degree of heat much below the boiling point. And, for this reason, the dyeing should always be stopped as soon as the colours have been sufficiently *rasied:* and, I am persuaded, that to obtain the brightest reds with the least discolouration of the *white* parts, it is always advisable that the dyeing liquor should never be made much hotter than the hand can bear; and that the boiling, if it be

deemed expedient, should take place afterwards with clean water in a separate pan; which will also remove a part of the discolouration of the white parts. Commonly two or three pounds of madder for each piece of calico are crumbled into the water, and being well mixed therewith, the pieces, tacked together by their ends, are put into the dyeing liquor as soon as it becomes blood-warm, and afterwards turned through it constantly, backwards and forwards over the winch, pressing down those parts of the calico which rise above the surface. It is desirable, that the colouring matter should have applied itself sufficiently within the space of an hour, and then the pieces should be turned out of the liquor immediately, and carried as soon as possible to a stream of running water and be there well washed, to obviate the *spotting*, to which they would otherwise be liable; and when this has been done, they are to be boiled in water with bran, (which removes a portion of the *brownish* colouring matter) and afterwards exposed upon the grass, with the well-known management and precautions; and this alternate boiling with bran, and exposure on the grass, are to be repeated until all discolouration by the madder has been removed from the parts to which no mordant or basis was applied, and some of the brownish part of the colour also detached from the red parts. The use of bran, for the purpose just mentioned, has been found to be unnecessary

in the East Indies, by those who have *there* practised the European methods of calico printing; exposure to the sun and air, and the application of water, being abundantly sufficient in that climate to produce the desired effect.

When sumach is intended to be employed with madder, it is thought best to apply it first, or separately, at the rate of about one pound of that which is *brightest*, and of the best quality, to each piece of calico, putting it into the water whilst cold, and turning the pieces by the winch, fifteen or twenty minutes through the liquor as soon as it becomes blood-warm, and taking care not to make it hotter than the hand can bear; after which the pieces should be rinced in water with a very little sulphuric acid, and dyed *immediately* with madder, or kept *under water* until dyed, otherwise the sumach, by absorbing oxygene from the atmosphere, will produce a troublesome discolouration of the parts intended to be left white.

It has been found practicable within a few years, to produce from madder upon calicoes, a *rose* or *pink colour*, by employing it with a large proportion of bran, which, by its acidity, hinders, in a great degree, the extraction of the brownish yellow part of the colouring matter of the madder, and its application to the calico; an effect similar to that which I lately mentioned as produced by the acid of tartar, in dyeing wool or woollen cloths. This employment of bran,

was lately brought into notice by a journeyman calico printer, named Growse, and the colour obtained by it was called Growse's *pink*. His process (which was cheaply purchased for one hundred guineas, by a subscription among the master calico printers,) was performed by putting into a copper, or dyeing pan, with water, three bushels of bran, and making the liquor boil about five minutes, then suffering it to cool, and adding sixteen pounds of the best crop madder, which, by stirring, is to be well mixed therewith, and in this mixture pieces of calico, previously impregnated, or printed with *strong* acetate of alumine, and afterwards well cleansed, are to be dyed, by passing or turning them quickly six or eight times backward and forward through the liquor; then rincing and washing them until fit for sale, without either branning or bleaching, as the acid derived from the bran served, in a great degree, to protect the white grounds from discolouration. It is, however, necessary to the success of this operation, that the proportions of bran and madder should be nicely adjusted, for where the former is in *excess*, the colour will be weak, and where it is deficient, the colour will be less rosy, and the white grounds more discoloured.

I have repeatedly found that a similar effect (i.e. that of obviating, in a considerable degree, the discolouration of the white grounds) might be

obtained by employing along with madder about one sixth of its weight of the best sumach; but this addition made the red incline more to the orange tint. The leaves and tops of the plant, which I received from Mr. Alderman Prinsep, under the name of *d'howah*, as mentioned in the preceding chapter, produced the like effect of hindering a discolouration of the white grounds, and without any sensible change of the madder red. A solution of glue being put along with madder into the dyeing vessel, manifestly obstructed the combination of the colouring matter with the aluminous basis, so that only a kind of salmon colour was produced.

M. Haussman (now of Longleback, near Colmar,) strongly recommends, in dyeing with madder, the addition of about one fifth or sixth of its weight of either powdered chalk or quick lime, to decompose or counteract a portion of sulphate of magnesia, supposed to be naturally contained in madder. He adds, that it was not until he had removed from Robec, near *Rouen*, where the water naturally holds *carbonate* of lime (chalk) in solution, that he discovered the error of an opinion which had been entertained by himself and other calico printers in that neighbourhood, who imagined that the superiority of their madder reds, was due *not to this quality* of their water, but to certain *useless* drugs which they employed, and withheld as a great secret;

and he asserts, that in all situations where the water does not contain some portion of carbonate of lime, the utility of putting it into the dyeing vessel along with madder, may be rendered manifest, by taking two pieces of calico, printed with *exactly the same mordants*, &c. and dyeing them separately with the same madder, and with no other difference than that of putting chalk into one vessel and not into the other; as the red dyed with the aid of chalk, will be found much brighter and more durable than the other, and more capable of supporting the action of bran, soap, &c. See Ann. de Chimie, tom. x. and lxxvi.

I have in vain tried, with a great variety of means, to produce a *prosubstantive red* from madder. Its colouring matter seems incapable of being fixed upon linen or cotton by any basis, unless the basis be applied *separately* from the colouring matter.

After these observations concerning topical or partial dyeing on calico with madder, I proceed to the application of it *generally*, (and without any reservation of white or other coloured parts,) to linen and cotton, either woven, or only spun into thread or yarn.

Two kinds *of red colour* are dyed from madder upon linen and cotton; one of these is the common madder red, and the other the *Turkey* red, to be treated of in the next article: both

are dyed upon the aluminous basis, but with a considerable difference in regard to the auxiliary means and modes of employing them. For the common madder red, linen or cotton, after being boiled in a weak lixivium of potash or soda, and well rinced and dried, is to be macerated in a decoction of powdered galls, employed after the rate of four ounces to every pound of linen or cotton to be dyed; and being equally impregnated with the soluble matter of the galls, and afterwards dried, the linen or cotton is to be alumed, by soaking it thoroughly in a saturated luke-warm solution of alum, employed also at the rate of four ounces to each pound of linen or cotton; after having previously neutralized the excess of its acidity, by adding to the solution one ounce of soda for every pound of alum: this being done, and the linen or cotton moderately and equally wrung or pressed, it is to be well dried, and afterwards alumed a second time, dissolving for that purpose half as much alum as for the first aluming, and adding to it the residue of the former solution. After this second aluming, the linen or cotton is to be again well dried, and then rinced, to remove any superfluous part of the alum which may not have been united thereto.

By substituting the acetate of alumine (formerly described) for the solution of alum, just mentioned, a more beneficial effect might be

obtained; but it would be attended with a considerable increase of expence.

The use of galls, in this operation, will be readily conceived, by recurring to what I have mentioned, at p. 356, and 357, of my first volume, concerning the effect of myrobalans, when employed by the Hindoos, in causing a more copious precipitation, and a more intimate union of the earth of alum, in or with the calico which had previously imbibed their astringent matter. That this is the only use of galls so employed, I presume, because I have found, by repeated trials, that when employed with madder in the dyeing operation, they add nothing to the durability of the colour.* Linen or cotton which has been thus impregnated with the aluminous basis, is to be dyed with the best crop madder, employing about three-fourths of a pound thereof

* For every other purpose, except that of decomposing the alum, and increasing the precipitation of alumine, and, perhaps, its closer union with the fibres of cotton, *galls appear to do harm* rather than good with madder, by diminishing the vivacity of its colour, and giving it a brownish tinge, without the smallest increase of its durability; on the contrary, I have observed, that when calico printed with acetate of alumine was divided, and one half dyed with madder only, and the other with madder and galls, the colour of the latter, besides a considerable degradation, was injured by being boiled with soap, and also by being exposed to the weather *sooner*, and in a degree considerably *greater*, than the half which had been dyed with madder only.

for each pound of the substance to be dyed, with the usual management and precautions; particularly that of raising the heat gradually, so that it may begin to boil in about fifty, or at most, sixty minutes, and taking it out of the dyeing liquor when the boiling has continued but a very few minutes; after which, being slightly rinced, it is to be dyed a second time in the same manner, and with the same quantity of madder. After the second dyeing, followed by the usual rincing and drying, it is commonly thought expedient to macerate the linen or cotton in a luke-warm solution of *soap*, (employing for that purpose about two ounces of the latter to each pound of the former) in order to give more vivacity to the red colour, and remove any adhering, but uncombined, colouring matter; afterwards rincing and drying, as usual.

Some persons have advised a weak solution of glue to be applied to the cotton, after it has been alumed, as before mentioned, believing that it would operate favourably in uniting the alumine more closely with the cotton and the tanning principle of the galls, and moreover give animal properties to the cotton. The effect of this application has not, however, appeared to produce any considerable benefit in the several trials which I made with it. By substituting the nitrate of alumine for common alum, a red somewhat brighter was produced; but, perhaps, the diffe-

rence would hardly compensate for the difference of expence.

Sumach is sometimes employed instead of galls, as a preparation for the madder red, and sometimes both are employed together. It can hardly be necessary for me to mention, that piece-work, when dyed, is made to pass through the dyeing liquor by turning it over the winch; and that thread or yarn in skeins is to be put into the liquor upon sticks.

ARTICLE II.

Rubia peregrina, Lin. Smyrna or Levant Madder, and its Application for dyeing the Turkey Red.

THE leaves of this species are perennial, commonly in fours, elliptic, shining, and smooth on the upper surface. It has been found wild in some few parts of England; but for the use of dyers has been all imported, chiefly from Smyrna, Cyprus, and Provence. It is called ali-zary, or lizary by the modern Greeks, and foijoy, or fouoy, by the Arabs. The best is cultivated in Bœotia, along the borders of the Lake Copais, and in the Plain of Thebes. It grows also in large quantities at Kurdar, and other places near Smyrna, as well as at Cyprus, whence, in 1760, M. Bertin, one of the French ministers, procured a large quantity of the seeds, which have since produced all the madder of Provence. Its roots have less parenchyma than those of the Zealand

madder; but they afford a colour somewhat brighter, and are, therefore, always preferred in dyeing the Turkey red. But as the people of the Levant, by whom this species is chiefly cultivated and exported, have not had ingenuity and industry sufficient to improve it like the Zealanders, by pounding and separating the skin and inferior parts of the roots; but have left them in their natural state; (whence they are commonly called *madder roots* in this country) the dyers of woollen cloths have not been able to produce from them, colours so bright as those obtained from the crop madders;* the finer colouring matter of the former being degraded by that of their skins and smaller roots; an inconvenience which is overcome by the dyers of Turkey red, in the last part of their process, as will hereafter be explained. The Levant dyers never employ the fresh gathered roots.

According to the best information which I have been able to obtain, the complicated process by which the *Turkey red* can *alone* be dyed, was many ages ago practised, and perhaps invented, by the inhabitants of Malabar and Coromandel; but with this difference, that instead of *madder*, they employed the roots of the *oldenlandia umbellata*, which will fall under our particular notice in

* Very recently, and since the above was written, mills have been erected in this country, to give the madder roots the same preparation as that of Zealand.

the next chapter. From India the knowledge and practice of dyeing this admirable colour, seems to have been carried to Persia, Armenia, Syria, and Greece, and, after a long interval, to France, in consequence of the accounts transmitted, at different times, by the ambassadors of that nation at Constantinople, of the means and methods employed to dye this red, particularly at *Andrinople*, and of the instructions which, on the faith of those accounts, the French government published, in 1765, under the title of "Memoire Contenant le procèdé de la Teinture du coton rouge incarnat *d'Andrinople* sur le coton filé." By this mode of introduction, the colour under consideration obtained, in France, the name of *rouge d'Andrinople*, and in Great Britain that of *Turkey red.*

The instructions, so published, were first carried into practice chiefly at or near Rouen, in Normandy; but for a considerable time they were attended by numerous failures and disappointments; though at present the Turkey red, from various improvements suggested by observation and experience, is supposed to be dyed in that part of France even more permanently, and with greater lustre, than in Greece or any part of the Ottoman Empire, or, I may probably add, of Europe.

In the year 1790, M. Pierre Jacques Papillon, who, after having been employed in dyeing the Turkey red in France, had practised it success-

fully at Glasgow, received a premium from the Commissioners and Trustees for Manufacturers in Scotland, in consideration of his communicating to Dr. Black, then Professor of Chemistry at Edinburgh, a description of his process; though, by agreement, it was to be kept a *secret* during a term of years, for the use of M. Papillon exclusively; and that term having expired; and the process having been published, I shall subjoin an account of the several operations of which it consisted, with remarks *upon each*, intended principally to explain its difference, where any occurs, with the correspondent operations in the two processes generally practised at Rouen, as they have been very lately published, by M. Vitalis, "Docteur es Sciences de l'Universite Imperiale; Professeur des Sciences Physiques au Lycée de Rouen, &c." in his "Manuel du Teinturier sur fil and sur Coton filé."*

* Until within a few years, the Turkey red was exclusively dyed upon cotton spun into yarn, but not woven: though, since Mr. Arkwright's invention, (by which as Mr. Wilson observes, "the cotton wool is carded and drawn forward lengthway of the harle, or filaments;" and being so spun) the thread or yarn is made much stronger, and also much more equal, and muslins woven from it, may with care be made to receive the Turkey red dye, and be even variegated by a reservation of *white* spots, &c. by passing the muslin through cylinders after it has been macerated in the oleaginous and other steeps, (in order that the latter may be equally expressed as is done with other piece-work which has im-

An Account of the Process for dyeing Turkey Red, *as practised by M. Pierre Jacques Papillion, viz.*

Step 1. *or Cleansing Operation.*

For 100lb. of cotton take
100lb. of Alicante barilla
20lb. of pearl ashes
100lb. of quick lime.

Mix the barilla with soft water in a deep tub, having a small hole near its bottom, which is to be stopped at first with a peg, but covered within by a cloth supported by two bricks, in order that the ashes may be hindered from either running through the hole, or choaking it, while the *lye* filters through it. Under this tub, another is to be placed to receive the lye; and pure water is to be repeatedly passed through the first tub, to form lyes of different strength, which are to be kept separate until their strength has been examined. The strongest required for use, must swim or float an egg, and is called the lye of six degrees of the French hydrometer, or "pese-liqueur." The weaker are afterwards brought to this strength, by passing them through fresh barilla; but a certain quantity of the weak, which

bibed only a single mordant) and finally, when the muslin has been dried, and previous to the dyeing operation, printing a strong *reserve* of oxalic or citric acid upon the parts intended to be preserved *white.*

is to mark two degrees of the above hydrometer, must be reserved for dissolving the oil, the gum, and the salt, which are used in subsequent parts of the process. The lye of two degrees is called the weak barilla liquor, the other is called the strong.

Dissolve the pearl-ashes in ten pails, (containing four gallons each) of soft water, and the lime in fourteen pails.

Let all the liquors stand until they become quite clear, and then mix ten pails of each.

Boil the cotton in the mixture five hours, then wash it in running water and dry it.

Remark.—At Rouen two courses of operations are practised to produce the Turkey red; one is called the *grey* course, (la marche en gris) and the other the *yellow* course, (la marche en jaune). In the former, the cotton, after being alumed, receives no more oil, but goes to the dyeing vessel, retaining the *grey* colour, which naturally results from its being impregnated with alum and galls in combination. But in the yellow course, the cotton, after being alumed, is again immersed in the oleagenous mixtures or steeps, to be mentioned hereafter, by which it acquires a yellow colour. The *grey* course may consist either of fifteen steeps, or of nineteen; and the yellow of twenty. The first of these courses has most similitude to that of M. Papillon, and it is this which I shall principally compare with the latter;

occasionally noticing any peculiarity in the yellow course.

At Rouen the first, or cleansing, operation (called decrusage) is performed with a very weak lye of soda, of only one degree of the hydrometer, pese-liqueur or aréometré of Beaumé, employing 150 gallons to 100lb. of cotton, which is to be boiled therein six hours, then drained, well rinced in running water, and afterwards dried. This operation is intended to *free* the cotton from all impure or extraneous matters; but not to produce effects like those of bleaching by exposure upon the grass, which it was, until lately, believed would lessen the durability of the colours to be subsequently dyed.

Step 2.—Bain bis, or grey Steep.

Take a sufficient quantity (ten pails) of the strong barilla water in a tub, and dissolve or dilute in it two pails-full of sheep's dung; then pour into it two quart bottles of oil of vitrol, one pound of gum arabic, and one pound of sal ammoniac, both previously dissolved in a sufficient quantity of weak barilla water; and, lastly, twenty-five pounds of olive oil, which has been previously dissolved, or well mixed, with two pails of the weak barilla water.

The materials of this steep being mixed, tramp or tread down the cotton therein, until it is well

soaked: let it steep twenty-four hours, then wring it hard and dry it.

Steep it again twenty-four hours, and again wring and dry it.

Steep it a third time twenty-four hours, after which, wring and dry it; and lastly, wash it well and dry it.

Remark.—The steep here precribed, contains three ingredients not employed, so far as I can recollect, by any other person; and one of these, I mean the sulphuric acid, seems to indicate a want of chemical knowledge in M. Papillon, because, by neutralizing the soda, it must obstruct the effect which the latter is intended to produce, (i. e. that of rendering the oil miscible with water) or at least render a greater proportion of it necessary, in order to obtain that effect. In regard to the other two of these ingredients, viz. the gum and sal ammoniac, I shall only observe of the former, that the quantity is by much too small to produce any considerable effect, either good or bad, without offering any opinion of the latter; because I am unable to form even a conjecture, respecting the purpose which it may have been intended to answer.

Did M. Papillon wish, by these additions, to give to his process some appearance of novelty or *peculiarity* which might render it more deserving of a reward?

At Rouen, the *bain bis* is prepared by steep-

ing twenty-five or thirty pounds of sheep's dung several days in a lye of soda, marking four degrees, which is to be afterwards diluted until it amounts to forty gallons; and the dung being squeezed and broken by hands, is afterward made to pass with the liquor through the bottom of a copper pan, provided with numerous small holes or perforations, into a tub containing twelve pounds and one half of fat oil, (huile grasse) and in this the oil and dung are, by sufficient stirring, to be well mixed with the lye, and with each other; and in this mixture, which contains but *half* the quantity of oil prescribed by M. Papillon, the cotton (i. e. 100lb.) is to be steeped, &c. as directed by the latter.

It is highly important after this, and each of the succeeding operations, that the cotton should be thoroughly and completely dried, by a stove heat, that of the open air in this climate not being sufficient, even in summer.

Step 3.—The White Steep.

This part of the process is precisely the same with the last in every particular, except that the sheep's dung is omitted in the composition of the steep.

Remark.—At Rouen this steep is prepared by mixing thirty-eight gallons of lye of soda with ten pounds of olive oil, (huile grasse) and stirring them until the mixture becomes uniformly

milky; which it will do without much difficulty, and remain so without any separation of the oil, if the quality of the latter be suited to this use; this they add to what may have been left of the former steep, and after mixing them properly, they impregnate the cotton therewith by the usual treatment; drying it after an interval of twelve hours, first in the open air, and afterwards by a stove heat. This steeping and subsequent drying must be repeated once, twice, or three times, according to circumstances to be mentioned hereafter.

Between this *white* steep and the following *gall* steep, it is the practice at Rouen to employ three salt steeps, and one cleansing operation.

In the first, (called *premier sel,*) twenty-four gallons of the lye of soda, marking two and a half degrees, are mixed in a tub, with the remnant of the white steep, and with this, the cotton is impregnated and dried, as in the former operations.

In the next, (called *seconde sel,*) the remnant of the last steep is mixed with twenty-four gallons of the lye of soda, marking three degrees, and the cotton steeped therein, and dried as before.

In the third, (called *troisieme sel,*) the remnant of the preceding steep is mixed with twenty-four gallons of the lye of soda, marking three and a half degrees, and with this the cotton is to be

impregnated and dried as before. The residuum of this steep, called *sikiou*, is preserved to be used in the brightening operation.

In the cleansing operation, called *degraissage*, the cotton is steeped one hour in luke-warm water, then wrung by hands, and afterwards washed in a stream of water, to remove any superfluous or uncombined oil, which, as is supposed, might obstruct the *equal* application and *uniform* effect of the following gall steep, and thereby render the colour when dyed unequal. After being so washed, the cotton is to be dried, first in the open air, and afterwards by a stove heat.

Step 4.—Gall Steep.

Boil twenty-five pounds of galls, bruised, in ten pails of river water, until four or five are boiled away; strain the liquor into a tub, and pour cold water on the galls in the strainer, to wash out of them all their tincture.

As soon as the liquor is become milk-warm, dip the cotton into it hank by hank, handling it carefully all the time, and let it steep twenty-four hours; then wring it carefully and equally, and dry it well without washing.

Remark.—This constitutes the eighth operation in the grey course at Rouen, where, as well as in M. Papillon's process, *galls in sorts* seem to be now employed, though it was formerly thought by the dyers of Turkey red, (as several of them

assured me) that only the *white* galls, or those from which, at maturity, the insects had made their escape, were fit for this purpose; the others being supposed to give an injurious brown stain to the cotton. But, probably, it has been since found, that this stain is removed without any trouble by the subsequent *brightening* operation. At Rouen the cotton, as soon as it has sufficiently imbibed the soluble matter of the galls, and been very moderately wrung, is spread as expeditiously as possible in the open air, if the weather be dry, or if not, under cover; but the drying is always finished by a stove heat.

Step 5.—First Alum Steep.

Dissolve twenty-five pounds of Roman alum in fourteen pails of warm water, without making it boil; skim the liquor well, and add two pails of strong barilla water, and then let it cool until it be luke-warm. Dip your cotton, and handle it hank by hank, and let it steep twenty-four hours; wring it equally, and dry it well without washing.

Remark.—At Rouen thirty or thirty-five pounds of the purest alum are commonly employed for this steep, with *only seven pails* of hot water; adding, when the alum has been dissolved, *two gallons only* of the lixivium, or lye, of soda, marking four degrees. But when these proportions are employed, the cotton is not subjected to a second

steep with alum, as directed in M. Papillon's sixth step.

Sometimes, however, at Rouen, two steeps with the aluminous mordants are employed, and in that case, twenty pounds of alum are dissolved for the first, and fifteen pounds for the second; leaving an interval of two days between them, during which the cotton should retain its moisture, after being slightly wrung from the first steep: it is, however, to be well dried before it goes into the second.

Step 6.—Second Alum Steep.

Is performed in every particular like the last; but when the cotton is dry, steep it six hours in the river, and then wash and dry it again.

Remark.—The explanation subjoined to the preceding *step* will suffice for this.

Step 7.—Dyeing Steep.

The cotton is dyed in parcels of about ten pounds at once; for which take about two gallons and a half of *ox blood*,* and mix it in the

* Blood, was probably first employed in this way with madder, from an expectation that the *red* colour of the former would augment that of the latter; though this must have been a fallacious expectation, as the red globules are not only incapable of being fixed, but are soon rendered almost black in less than a boiling heat; but I am persuaded, notwithstanding, that this employment of blood is beneficial, by affording something which contributes to fix the madder colour, though the

copper, with twenty-eight pails of milk-warm water, which are to be well stirred, then add twenty-five pounds of madder, and stir the whole well together; then having beforehand put the ten pounds of cotton on sticks, dip it into the liquor, and move and turn it constantly one hour, during which gradually increase the heat, so that the liquor may begin to boil at the end of the hour. Then sink the cotton and boil it gently one hour longer, and lastly, wash and dry it.

Take out so much of the boiling liquor as will leave the remainder only milk-warm, when mixed with as much fresh water as may be required to fill the copper again, and then proceed to make up a dyeing liquor, as before, for the next ten pounds of cotton; and so proceed in succession with the whole.

Remark.—At Rouen the cotton is dyed in parcels of twenty-five pounds each; and the dyeing vessel is of a quadrangular form, containing about 100 gallons of liquor. One quart of ox blood is employed for each pound of cotton, with two pounds of Provence madder, or one pound of the latter with one of Smyrna madder.

particular part of it, which produces this effect has not been ascertained. It is thus that, under the impulse of error, we sometimes stumble upon useful truths: an ignis fatuus may lead the benighted wanderer into a *ditch*, or it may conduct him to an hospitable mansion.

Some persons, however, think it best to effect the dyeing by two separate operations, employing half of the before-mentioned proportion of madder for one dyeing, and half for the other; but always taking care not to dry the cotton between the first and second dyeings. There are, moreover, some at Rouen who give cotton another alum steep between these dyeing operations, employing for that purpose half as much alum as was used for the first steep; and afterwards washing, &c. as usual.

Step 8.—*The Fixing Steep.*

Mix equal parts of the grey steep liquor, and of the white steep liquor, taking five or six pails of each. Tread down the cotton into this mixture, and let it steep six hours, then wring it moderately and equally, and dry it without washing.

Remark.—For this steep they employ at Rouen the sikiou, mentioned in my remark upon the third step; but the application of it is considered as a part of the following step, or operation.

Step 9.—*Brightening Steep.*

Ten pound of white soap must be dissolved carefully and completely in sixteen or eighteen pails of warm water; because if any little bits of the soap remain undissolved, they will make spots in the cotton. Add to this, four pails

of strong barilla water, and stir it well. Sink the cotton in this liquor, keeping it down with cross sticks, and cover it up; boil it gently two hours, when, being washed and dried, it will be finished.

Remark.—This constitutes the 14th operation in the first set of *grey courses* at Rouen; where, after having macerated the cotton with the sikiou, as just mentioned, they *boil* it five or six hours with six or eight pounds of white soap, previously dissolved in one hundred and forty-five gallons of water, and in a vessel covered at the top, so as to leave only a very small opening for the necessary escape of the steam; which might otherwise occasion an explosion. The effect of this ebullition with soap is to dissolve and separate from the cotton all the yellowish brown part of the madder colour, which may have been applied to it in the dyeing operation; and by this separation to change the colour from the dull brownish red, which it would otherwise retain, to a bright lively colour, nearly equal to that of the finest cochineal scarlet. It is only by the *singular* degree of fixity which the *pure red* part of the madder colour acquires, in consequence of the operations just described, that this beautiful red can be obtained; for though the reds given from madder in calico printing, are sufficiently durable for all common uses, they are not fixed sufficiently to bear without injury, that extent of boiling with soap, which is necessary to separate

the yellowish brown part of the colour, and produce the pure *vivid red*, which results from the operations under consideration. Such, indeed, is the stability of the Turkey red, when well dyed, that some of the persons employed in dyeing it, have assured me that their colours would sustain boiling with soap for the space of thirty-six hours without injury.*

In addition to the steps or operations prescribed by M. Papillon, they employ another at Rouen, called *rosage*; which is intended to make the *red* incline more to the *rose* colour, and at the same time to increase its vivacity.

For this operation, with the former quantity

* The preceding operations, agree very nearly with those practiced at Thessaly and in other parts of Greece, as described in Baujour's Commerce of Greece, (p. 180, and seq.) and in the Memoir of M. Felix, (Ann. de Chimie, tom. xxxi. p. 195, &c.) though the cleansing is there performed by a lixivium of wood-ashes and soda, made caustic by lime. The grey steep in Greece consists of a lixivium of soda combined with sheep's dung, and with the fluid matter of the second cavity of their stomachs, or those of other ruminating animals, and olive oil; but this is applied at four or five several times, drying between them, and these repetitions of the grey steep, supply the *place* of the *white*. After galling in the usual manner, the alum steep is applied *twice* with an interval of two days, and in this steep the solution of alum is partly neutralized by soda. The dyeing is performed with the madder of the Levant, mixed with sheep's blood: after which the brightening operation, or *avivage*, is effected, by boiling the dyed cotton with a weak lixivium of soda.

(100lb.) of cotton, they dissolve in one hundred and forty-five gallons of water, sixteen or eighteen pounds of white soap; and as soon as the liquor begins to boil, they add to it from one pound and one half, to two pounds of the crystallized muriate of tin, (mentioned at p. 555, of my first volume) previously dissolved in two quarts of water, and mixed with eight ounces of single aquafortis; and having equally dispersed this mixture through the boiling solution of soap, by stirring, &c. the cotton is put into it, and boiled with the same precautions as in the brightening operation, until the desired effect has been obtained; which is to be discovered by frequent examinations. Care must be taken not to employ more nitric acid, or aqua fortis, than the quantity here mentioned, least it should decompose the soap, and cause the oil to separate, and rise to the surface of the liquor.

M. Vitalis supposes, that a metallic soap is formed in this operation; the oxide of tin being, as he thinks, dissolved by the soda.

That a solution of tin, employed in this way, should add something to the vivacity of the colour, is very probable from what I have seen of its effects upon the madder red. But I am convinced that it can add nothing to its fixity on cotton, unless the nature of the latter should have been greatly changed by the impregnations which it receives by the operations recently described. M. Vitalis

adds, however, (p. 98,) as a discovery of his own, and one which, as he says, has been successfully tried upon a large scale, that an acid sulphate of potash, employed with soap in the proportion of two or three pounds of the former, to one hundred pounds of cotton, will answer all the purposes of the muriate of tin, giving a particular and very pleasing shade to the Turkey red.

In regard to the second of the grey courses employed at Rouen, I must observe, that it differs from the first, by having two additional repetitions of the grey steep, (with dung) and four of the white steep, (after the first) with two gall and two alum steeps.

In the *yellow* courses, after the first gall and the first alum steeps, two of the *white* are interposed, with two of the *salt* steeps (sel) in addition to the like number given before the first galling; and these are succeeded by a second gall steep, and a second maceration in a saturated solution of alum; after which, the cotton, being well dried and then rinced, is dyed with Provence madder alone, in the proportion of two pounds and one half of the latter to each pound of cotton, or with a like quantity of Provence and Smyrna madders mixed in the proportion of one-third of the latter, to two-thirds of the former. This *yellow* course, as may be supposed, is intended to produce the richest and most durable colour.

M. Vitalis asserts, (p. 100,) that it is impossible

to produce a fine and permanent Turkey red, without employing in the different operations, forty pounds of oil for each 100lbs. of cotton; and that the stove heat for drying, ought not to be less than 55 degrees of Recurmur's scale, which is equal to 158 of Farenheit's.

To this account of the different courses and operations, employed to produce the colour in question, I shall subjoin an extract of certain observations respecting it, published in the 26th volume of the Ann. de Chimie, by M. Chaptal, (late minister of the interior of France,) which are the more valuable, as being the result of a great portion of chemical science, added to an extensive *practical* acquaintance with these operations, and their effects.*

"It is known," says M. Chaptal, "that cotton does not take the madder red permanently, unless it has been sufficiently impregnated with oil. This preliminary preparation is given to cotton by a cold saponaceous liquor, formed by a combination of oil, with a weak lixivium of soda. All kinds of soda, and of oil, however, cannot be employed for this purpose. In order that the soda may produce suitable effects, it must be *caustic*, and contain but little muriate; and this

* See also, l'Art de la Teinture du Coton en Rouge, &c. par M. J. A. Chaptal, Membre, et Trésorier du Sénat, Grand Officier de la Legion d' Honneur, &c. &c. 8vo.

causticity must be produced by calcination, and not by an admixture of lime, which gives a brownish tinge to the red.

"The carbonate of soda, and soda mixed with a considerable proportion of muriate, will combine but imperfectly with oil; and, therefore, soda either long prepared, or impure, is unfit for this purpose.

"The choice of the oil is of as much importance as that of the soda. The former, to be good, should unite very perfectly with the lye, or lixivium of the soda, and remain in a permanent state of combination. The oil fittest for this dye is not fine oil, but that which contains a large portion of the extractive principle.* The former

* The oil employed by the dyers of Turkey red in Great Britain, is imported chiefly from Italy under the name of Gallipoli-oil. After the finest olive oil which rises to the surface has been drawn off, the heavier, which is combined with a considerable portion of mucilage, is separated from the dregs at the bottom of the cistern, and this constitutes the Gallipoli oil. Its *mucilaginous* part, enables the *oleaginous* to unite, and form a mixture of a milky appearance, with a *weak* lixivium of soda, which the purer oil would not do. If when this mixture is formed, it preserves its milky appearance 24 hours without any separation or collection of oil in globules upon the surface, it is deemed suitable for the Turkey red dyers. In the East Indies, whence the Turkey red was derived, the oil of sesamum, (obtained from the seeds of the vanglo plant) is commonly employed for this purpose, (as, indeed, it is by the Turks) and when this is wanting, they substitute hogs' lard, as will be seen in my

does not preserve its state of combination with the soda, without such a degree of strength in the lye as would prove injurious to the subsequent operations. The latter forms a thicker and more durable combination, and requires only a weak lye of one or two degrees.

"The necessity of producing a perfect and intimate combination of the oil and the lye of soda, be readily perceived, by considering that the lye is only employed to *divide*, dilute, and convey the oil in an equal manner to all the parts of the cotton, and, therefore, if the oil be not well mixed, the cotton made to pass through this mixture will take the oil unequally, and the colour be but badly united. Hence it happens that the

next chapter; and, indeed, the Abbè Mazeas has asserted, in a "Memoire" printed among those of the Royal Academy of Sciences at Paris, (viz. those of the "Scavans Etrangers" tom. iv.) that he had produced better effects in this way with hogs' lard, than it was possible for him to do by any other greasy or oily matter; and, we are informed by Professor Pallas, that the Armenians, who have been, by the troubles in Persia, driven to Astracan, do there successfully employ fish oil to dye the Turkey red. It seems, therefore, that *animal* oil, or fat, will answer the purpose in question as well as the vegetable. The circumstance of most importance seems to be, that of not employing those oils which are called *drying* oils, such as that of lintseed, which is said to blacken the colour in some degree, probably by absorbing oxygene, and it seems to be this property, which has caused it to be employed to improve the black colour dyed upon cotton.

workman places the whole secret of a well united and strong colour, in the choice of good oil and proper soda: and, consequently, the oil ought to be rather in excess than in a state of absolute saturation, for in the latter case it would abandon the cotton in the subsequent washings, or rincings, without benefiting the colour.

"When the cotton has been properly impregnated with oil, it is subjected to the operation of galling. The use of the gall-nuts is attended with several advantages: 1st. The acid which they contain, decomposes the saponaceous liquor with which the cotton has been impregnated, and fixes the oil on the stuff. 2nd. The character of *animalisation* which the galls possess, and *impart*, predisposes the cotton to receive the colouring matter. 3rd. The astringent principle unites with the oil, and forms with it a compound which darkens at it dries, which is not very soluble in water, and which has the greatest affinity with the colouring principle of the madder. The dyer may acquire a competent knowledge of this last combination, and study its properties, by mixing a decoction of gall-nuts with a solution of soap.

"It follows from these principles: 1st. That the place of the gall-nuts cannot be supplied by any other astringent, let the quantity employed be what it may. 2nd. That the decoction of galls ought to be employed when warm, that the decomposition may be speedy and perfect. 3rd.

That the galled cotton ought to be speedily dried, in order to prevent its assuming a dark colour, which would injure the brightness of the red intended to be given to it. 4th. That dry weather ought to be chosen for the process of galling, because in moist weather, the astringent principle communicates a dark colour, and dries slowly. 5th. That the cotton ought to be pressed together with the greatest care, in order that the decomposition may be effected in an equal manner, at every point of the surface. 6th. That a proportion ought to be established between the gall-nuts and the soap; if the former predominates, the colour will be dark, if the latter, a portion of the oil, not combined with the astringent principle, will escape by the washings, and the colour will be poor.

"The third mordant employed in dyeing cotton red, is the sulphate of alumine (alum). This substance not only has of itself, the property of heightening the red of madder, but it contributes also, by its decomposition, and the fixation of its alumine, to give solidity to the colour. To judge of the effects of alum in dyeing cotton, it will be sufficient to mix a decoction of gall-nuts with a solution of alum. The mixture becomes immediately turbid, and a greyish precipitate is soon formed, which, when dried, will prove to be insoluble in water and the alkalies.

Every thing that takes place in this experiment

of the laboratory, may be observed in the process of aluming, for dyeing. Cotton, when galled and plunged in a solution of the sulphate or acetite of alumine, immediately changes its colour and becomes grey; the bath presents no precipitate, because the operation takes place in the tissue of the cloth itself, where the production remains fixed. But if the galled cotton be passed through a solution of alum that is too warm, a portion of the galls will escape from the tissue of the stuff, and a decomposition of the alum will take place in the bath itself, which will diminish the proportion of the mordant, and impoverish the colour.

"We have here, therefore, a combination of three principles (oil, the astringent principle, and alumine) which serve as a mordant for the red dye of madder. Each of them employed separately, produces neither the same fixation, nor the same lustre in the colour.

"This mordant, undoubtedly, is the most complex of any which is known in dyeing; and it presents to chemists a sort of combination eminently deserving of their utmost attention. It is only from a great degree of precision in this combination, and a great portion of judgment in the artist who produces it, that a beautiful colour can be expected; but though it be possible for him to conduct himself without error, through the labyrinth of these numerous operations, by taking the clue of experiment as his guide, he will find it very diffi-

cult to simplify his progress, or bring it much nearer to perfection. It is only by reasoning on his operations, and calculating the result as well as the principle of each, that he can hope to become master of his processes, to correct their faults, and to obtain invariable products. Without this, the practice of the most experienced artist, will afford nothing in his hands, but the discouraging alternative of success and disappointment. I wished, therefore, in this short analysis of the process for dyeing Turkey red, which is the most complicated of all, to give an instance of what chemistry can do in the arts, when its principles are properly applied. I will venture to assert, that the most uninformed workman will here find the principle of his art, and the rule of his conduct."

As I had long accustomed myself to respect the opinions of M. Chaptal, who, by being extensively engaged in dyeing the Turkey red, had obtained very superior opportunities of discovering the truth respecting it, and as his reasonings concerning the effects of the various applications under consideration, were so well calculated to produce conviction, I, without much hesitation, some years ago, adopted his general conclusion, that *the result of all the operations for dyeing this colour, is that of producing a combination of three substances, alumine, oil, and the astringent principle* ("*l'alumine, l'huile, et leprincipe astringent*") *and thus forming a mordant, which (in his opinion) is the only*

one capable of rigorously fixing the madder colour. See his Memoir dans le Recueil des Memoires de l'Institut, vol. ii.

But after having adopted this conclusion, I was forced to believe, that a suitable, and perhaps more efficacious, combination of these *three* substances, might be made with greater simplicity, expedition, and benefit, than by the complicated, and, in many respects, incongruous mixtures and operations commonly employed for that purpose; and in this belief, I undertook, and was occupied, during almost all the year 1809, by a series of experiments, in which oily, or saponaceous mixtures, decoctions of galls, and solutions of alumine, were applied to cotton, with every possible inversion or change in the order of their successive applications, and with so many variations in their absolute, as well as relative proportions, and in all the circumstances likely to influence their effects, that, if it had been possible, by these means *alone*, to enable cotton to acquire from madder a colour equal to the Turkey red, it must, as I confidently believe, have been produced. The best results, however, of all my experiments were only reds, not considerably better than those frequently given with madder by calico printers, in regard to their power of sustaining the action of soap, akalies, and the air; though they were able a *little* longer to resist the force of a diluted nitric acid; a small immunity which was probably derived from the com-

bination of oil and the astringent matter of the galls with the alumine, which last is the only basis of the madder red given to printed calico.

Since these failures, and *in consequence of them,* I have found it necessary to suppose, that some matter, not to be obtained from oil, galls, and alum, is necessary to the stability of the Turkey red; and this matter I have suspected to exist in the dung and the intestinal liquor of ruminating animals, or in that of their second stomachs, of which no use was made in my experiments, because they were not included by M. Chaptal among the things *required* to produce the colour in question, and because M. Le Pileur d'Apligny,* M. Felix,† and others, had declared them to be of no use towards fixing the Turkey red.‡

At pp. 363 and 364 of my first volume, after

* See Art de la Teinture des fils et Etoffes de Coton.

† See also his "Memoire sur la Teinture, & le Commerce du Coton filé Rouge, dela Grece," in the Ann. de Chimie, tom. xxxi.

‡ It must also be observed, that I did not employ either sheep's or ox's blood with the madder, in the dyeing part of these experiments; for though M. Chaptal believes that it may give more *vivacity* to the colour, he does not include it among the substances, contributing to its *fixity*, and I had it principally in view, to ascertain the matters *necessary to produce that effect.* Had I employed, and succeeded by employing, *blood,* my purpose would have been frustrated by reason of the *various matters* of which it consists, and which would have left me in the same uncertainty as before.

mentioning the use made by calico printers, of *cow-dung*, to remove the superfluous part of their aluminous mordant, I have said there was " reason to believe that the cow-dung, by the gastric juices, gelatine and albumen, which it contains, afforded a very beneficial impregnation to the printed calico, of *some animal matter*, which, combining with the mordant, serves to bind it more strongly to the cotton, and afterwards to increase its attraction for the colouring matter, like some of the animal impregnations which are so necessary for the Turkey red." This opinion had been adopted, after all my endeavours to produce the colour in question from oil, galls, and alum, had proved useless; and when I had formed the opinion which I retain (and which by his " Memoire, presenté a l'Institut National" de France, appears also to be entertained by M. Vitalis,) that the gelatine contained in the dung of ruminating animals, or the albumen which it also affords *in a much larger proportion*, or some other matter, derived from it, and probably from their blood, is essentially necessary to produce that fixity, as well as beauty of colour, for which the Turkey red is so much admired, though at present, we only know with certainty of this matter, and this colour, that both may be communicated by the successive applications and operations which have been recently described, but of the *particular* effect of either, we are in a great degree ignorant.

The first operation ("decreusage") in each of the several courses, is intended, and may be deemed sufficient, to remove from the cotton, every thing which could obstruct, either the application or combination of the several matters required to produce the Turkey red; and, therefore, the *end of all the subsequent operations ought to be, that of adding*, or promoting the combination of something, required to enable the cotton to imbibe and permanently retain the colouring matter of the madder; but several of these operations must, as far as I can judge, produce a different effect, by *dissolving* and *removing* a considerable part of the matters antecedently applied by the other preceding operations: such, for instance, must be the effect of the *salt* steeps, consisting of solutions of soda, employed subsequently to those containing the dung, the saponaceous mixtures, and the decoction of galls; and, therefore, unless these latter steeps were either hurtful, or excessive in their strength or quantities, it must be inferred, that the salt steeps would do harm by diminishing, at least, the benefits to be derived from the previous application of the dung, oil, and galls.

M. Chaptal supposes, as others, when reasoning on this subject, have done, that the only good purpose to be answered by combining soda with the oil, (necessary for the Turkey red) is that of rendering the latter miscible with water. But is it necessary that the oil should be mixed with

water? If it be employed in sufficient quantity it will, while unmixed, *penetrate* the cotton as *thoroughly* and *equally*, as it does when formed into the saponaceous mixture, and, perhaps, more so; and though I once imagined that cotton, which had imbibed pure olive oil, so as to be saturated therewith, might not afterwards freely admit the astringent matter of galls, or the alumine; or that the oil would afterwards obstruct the application of the colouring matter, in the dyeing process, I have found, by repeated experiments, that no such effect is produced by oil so imbibed; but, on the contrary, that oil attracts and unites with the colouring matter of madder, and that cotton, even when the aluminous mordant has been first applied to it in spots, as by calico printing, may be soaked repeatedly in pure olive oil, and being merely squeezed to separate the superfluous part of the latter, it may be put into a dyeing vessel with madder, and there made to receive the colour most freely and copiously *upon the spots* or parts which had been previously alumed; the attraction of the aluminous basis for the madder colours, being rather promoted than lessened by this *interposition* of the oil; though it must be confessed that the latter did not appear to render the colour much more durable than it would otherwise have been. This being the case, the only reasonable motive for mixing the oil with water, must depend upon a belief, that while

unmixed it cannot be applied equally and thoroughly, without being applied in excess; but in opposition to this belief, I may adduce the practice of the Armenians, at Astracan, who, for their red dye, as we are informed by professor Pallas, soak their cotton in pure unmixed *fish oil*, during seven successive nights, taking it out of the oil and exposing it to the sun and air, during each succeeding day; and then, after rincing it only in running water, immerse the cotton in a steep or decoction of galls and the leaves of sumach; then dry, and afterwards alum it, for the subsequent operation of dyeing with madder.* These facts seem at least to render it probable, that the union of an alkali with oil is not necessary, to *obviate the application of it too copiously*; and that if it be intended to remain in combination with

* M. Bourdier, a physician, who had resided eleven years at Pondicherry and other places along the coast of Coromandel, asserts, that at *Masulipatam and Pulicat*, (where the reds are excellent) the cotton, after being dyed, is soaked either in the oil of sesamum, or in melted hogs' lard; and the oil being afterwards pressed as much as it can be from the cotton, the latter is exposed to the sun and air for some days; that this operation is repeated three times, after which the cotton is well washed. He says, that hogs' lard is preferred to oil for this use, and that the fine red handkerchiefs of Pulicat and Masulipatam have all been so treated. See "Mem. Geographiques, Physiques, &c. sur l'Asie, l'Afrique, et l'Amerique," tom. 1. Pp. 207, 208.

the cotton, such an union, by rendering it miscible with water, must counteract that intention, and make the oil liable to be, in a great degree, removed by some, at least, of the subsequent steeps.

That so much of uncertainty and obscurity should still prevail, in regard to this very estimable and extraordinary colour, is to me a matter of deep regret; and if my life should be prolonged a few years, and I *should be enabled to choose my occupations*, no endeavours of mine will be wanting to elucidate the subject; being persuaded, that by doing so, I may not only enable the Turkey red dyers to produce their colour at much less expence, but that this elucidation will throw a most beneficial light upon other parts of the art, and afford means also of adding to the beauty and stability of many other colours.

I have thought it expedient in this manner to endeavour to correct an error, which has lately become prevalent, I mean that of supposing that the true principle or cause of the fixity of the Turkey red had been discovered or ascertained; as this error must necessarily obstruct the attain ment of truth, by leaving no motive for subsequent inquiries, or experiments, on this subject.

ART. III.

Rubia Majrt'h, or Manjit'ha, of the Hindoos; and Majisht'ha of the Sanscrit.

This species of madder was imported, though I believe in a small quantity, by the French East India Company, about the year 1760, under the name *mongister*; and sometime afterwards, by the English East India Company, under the name of *majesto* root. More recently the importations into Great Britain have increased, and it has acquired, in the Company's sale catalogues, the names of *manjit*, and *mungeet*. It has appeared to consist of the *stem* of the plant, commonly six, eight, or more feet in length, and of twice the diameter of a goose quill, continued from the upper part of the root, (an inch or two in length, and commonly twice as big as the stem) bent into a form somewhat circular, and injudiciously formed into loose bundles, occupying unnecessarily much space, and consequently, incurring a great and needless expence for freight. Both the root and stem, when broken, appear internally of a reddish colour, like that of madder. Wishing to obtain some more accurate information concerning this plant, than I had been able to procure, I questioned Dr. Roxburgh on the subject, previous to his last embarkation for

India, and was assured by him, that it was unquestionably a species of rubia, or madder; and that it, in his opinion, might very properly be distinguished, by giving it as a trivial or specific name the Hindu appellation of manjit'h; which I have accordingly done; as I find Dr. Fleming, on the same authority, has also done in his valuable account of East Indian drugs, (printed in the 11th volume of the Asiatic Transactions, 4to) where he observes, that this species of madder is indigenous in *Nepal*, and is used by dyers and calico printers, in the same manner as the rubia tinctorum is in Europe. Dr. Roxburgh represented this to me as a creeping or climbing plant, and the stem as spreading or rising to a great extent; and he added, that unlike the stem of the rubia tinctorum, this of the manjit'h seemed to be preferred to the roots for dyeing; a circumstance which might be expected to render it *a very cheap dyeing drug*.

From the results of a great number of experiments, I conclude the colouring matter of this species of madder, in its general properties, to resemble very nearly that of the rubia tinctorum, but with this disadvantage, that on cotton and linen, its red is not so durable as that of the latter, though in calico printing it gives much less stain to the white grounds, and, therefore, requires much less branning, and exposure on the grass. On the other hand, I find its red colour to be more bright

and lively upon wool or woollen cloth when dyed with it, than that of the Dutch madder, and nearly, perhaps quite, as permanent; especially when solutions of tin are employed as the mordant. With these and the rubia manjit'h, I have repeatedly given to broad-cloth a scarlet, which, seen by itself, might be supposed to have been dyed from cochineal, though when contrasted and compared with cochineal scarlets, a difference obviously presented itself, not in the vivacity of these colours, but in a greater inclination to the yellow tint, in those dyed from the manjit'h. This latter defect may, however, be easily removed, by employing a portion of cochineal with the manjit'h; and by this mixture good scarlets might be produced with a considerable diminution of expence. I have in the former volume, recommended such a mixture of cochineal with Dutch crop madder; but the manjit'h is, I think, greatly preferable for this purpose. In regard to the durability of colours, given by the latter to cloth, with the basis of tin, I have ascertained, by sufficient trials, that it is fully equal to that of the cochineal scarlet. But on cotton *this basis* produced no more stability of colour from the manjit'h than it does from cochineal, though I employed it with a variety of auxiliary matters, such as galls, glue, oil, &c. Some very pretty reds have, within a few years, been given to muslins from this vegetable with an alumi-

nous basis, and some addition, which is, I believe, a secret.

With iron and other metallic bases, this vegetable produces colours differing but little from those given by the same means, with Dutch madder.

After this statement, it will not be thought extraordinary that I should strongly recommend an increased importation of this dyeing drug, especially for the dyeing of woollen cloths, to which it has not, I believe, been hitherto applied, except in my own experiments on a small scale, though it certainly is preferable to Dutch madder for this purpose; and by grinding, and close compression in casks, or other packages, capable of excluding moisture, the expence of freight might be lessened more than one half, without any danger of injuring the quality of the manjit'h.

There is another species of madder commonly used in China and Japan for dyeing, viz. the rubia cordifolia, described by Thunberg, (Jap. 60.) but I have had no opportunity of making any experiment with it.

CHAP. IV.

Of Vegetables affording Red Colouring Matters, nearly similar to that of Madder.

"Most of those useful arts, and admirable inventions, which are the very support of mankind, and supply them with all the necessaries and conveniences of life, have at first been the production of some lucky chance, or from slight and contemptible beginnings, have been, by long experience, curious observations, and various improvements, matured, and brought to perfection."

BISHOP POTTER'S ARCHÆOLOGY GRÆCA, vol. ii. p. 120. 3d edition.

ART. I.

Oldenlandia umbellata. Umbelled Oldenlandia of Roxburgh. The Ché or Chay, Chayaver, or Saya-ver, and Imburel of the Tamuls; and Tsheri-vello of the Telingas.

THIS plant, like madder, belongs to the natural order of stellatæ, and its roots are universally, perhaps exclusively, employed along the coast of Coromandel, and that of Malabar, to afford the durable reds for which the cotton yarn, and chintzes of those parts of India, have long been greatly esteemed.

Dr. Roxburgh, in his accurate and splendid work on the plants of Coromandel, describes this as being a small biennial, rarely triennial plant,

growing spontaneously in very light dry sandy ground near the sea;* and as being moreover extensively cultivated, especially on the coast of Coromandel.—The cultivated roots are very slender, and from one to two feet in length, with a few lateral fibres; but the wild are shorter, and supposed to yield one-fourth part more of colouring matter, and of a better quality; and this resides almost entirely in the *bark* of the roots, which, when they have been recently gathered, is of an orange colour, and tinges the spittle yellow, though by being long kept, the roots become apparently colourless, or at most only retain a very pale straw colour. The roots gathered at the end of their *second* year's growth are considered as the best; but the farmer does not find it profitable to let them continue in the ground after the *first.*

I have mentioned at p. 356 of my first volume, the employment of these roots by the natives of Coromandel, &c. for calico printing, or rather *chintz painting;* but they require to be more

* Dr. James Anderson, late Physician-general to the East India Company, at Madras, in certain printed letters to Sir Joseph Banks, asserts that these roots "will only yield colour when cultivated on the *sea* coast:" whether they derive any thing useful from the vicinity of the ocean, excepting a loose sandy soil, I know not. The roots produced in stiff clayey ground, are said to be of little or no value.

particularly noticed, in regard to the use which is there made of them in dyeing that beautiful and lasting red colour upon cotton, which seems to have preceded, and can only be equalled by the Turkey red; and by comparing the means and operations employed to produce these colours, it will be found, that those which afford the Turkey red, must have been *suggested*, at least, by a knowledge of those antecedently employed with the ché or chay root.

It is remarkable, that though, (as was formerly mentioned,) an aluminous basis is prescribed and employed for the colour of this root, by all the instructions respecting its use in *calico printing*, and though a similar basis is particularly required for the reds dyed with it, upon calico, *when no oil is employed*, yet no mention is made of any such *basis*, in the accounts given by Father Cocurdoux and others, of the means employed by the dyers in Coromandel, and Malabar, to produce that colour which is analogous to the Turkey red. In these accounts they are said to form a mixture similar to the grey steep (or *bain bis*) lately described, excepting that instead of soda, they employ a lye of wood, or other vegetable ashes, and instead of Gallipoli oil, that of gingelly or sessamum, which is rendered milky, by combining it with the alkaline lixivium; and to this they add either goat's or sheep's dung, which being dissolved, and equally dispersed through the

mixture, they steep therein the cotton yarn, (previously cleansed by repeated macerations in water, and dryings in the sun) during nine or ten successive nights; taking it out every morning, and spreading it widely to the sun's rays, during the day; after which the yarn is well rinced and dryed. This being done, instead of *galling*, as in the Turkey red process, a cold infusion is prepared from the powdered leaves of the memecylon capitellatum,* commonly called *cassa*, or *cacha* leaves, (which have an *astringent* taste) and in this the cotton is steeped once or twice, and dried after each steeping; by which it acquires a full deep yellow colour. After this it is macerated in another cold infusion of the bark of the roots of the nana, or nona tree, (which appears to be a species of guilandina) and afterwards dryed. But though in most places, these infusions are applied separately, they are mixed in some; particularly at Masulipatam.

By these macerations, and subsequent dryings, and without the mention of any aluminous or other basis, the cotton is said to be prepared for the dyeing operations, to be described hereafter.

* Dr. Roxburgh describes this as, being, in general, a shrub, though sometimes growing to the size of a large tree. It is the *Calamsaly* of the Malabars, and *allie* of the Gentoos.

The Abbé Mazeas having made himself acquainted with the accounts of these operations, as given in the 26th and 27th "Recueil des lettres Edefiantes," and in certain manuscript relations, some of which were procured by M. du Fay and others, furnished by M. de Rabec, (who had then lately returned to France from India) and being persuaded, that in reality no aluminous basis was employed, to produce the red colour under consideration,(because no mention was made thereof in either of these accounts or relations)he assiduously occupied himself with this subject, and endeavoured not only to produce a similar colour without the aluminous basis, but to discover and explain the principle or philosophy of an effect, so extraordinary. He was perfectly aware that an aluminous basis had been constantly employed both in Turkeyand France for the Turkey red, and that all the dyers of that colour firmly believed, that it could not be produced without that basis ; but he considered this as an erroneous opinion, and endeavoured to account for its existence, by supposing, that the Turks, after being informed of the East Indian process, must have failed in their attempts to carry it into practice, and that after this failure, they had with more success resorted to the means employed by Europeans for dyeing thread and yarn ; I mean those of aluming and galling ; which had thus been unnecessarily superadded to those employed on the coast of Mala-

bar and Coromandel. It appears from his memoir, intitled "Recherches sur la cause Physique, de l'adherence de la couleur Rouge aux toiles peintes, qui nons vient des cotes de Malabar & de Coromandel," and from his Appendix to that Memoir, (printed among the "Memoirs de Mathematique et de Physique," presented to the Royal Academy of Sciences at Paris, "par divers Savans," tom. iv.) that all his endeavours to produce the desired colour without an aluminous basis, were unavailing, until he had *substituted hog's lard* for the vegetable oil commonly employed; but that with this substitution, he succeeded in dyeing *one small hank* or skein of cotton yarn, ("un petit écheveau de coton,") with a red colour which supported boiling with soap, ("qui a resisté au de bouilli du savon;*) and considering this as a sufficient evidence of the practicability of producing the desired colour, without any aluminous basis, he proceeds to reason upon, and explain, the supposed fact, without any discoverable attempt to establish or confirm it by a *second* experiment, though from its most extraordinary *and* incredible result, he ought to have considered several repetitions of his experiment, and with

* He does not say how long it did this. It might have been for even less time than the common madder red will bear this trial.

constant success, as being necessary to convince others, that he was neither deceived himself, nor been inclined to deceive. But the philosophers of that time (1774) appear to have been so indulgent, that no one publicly questioned this supposed fact, and the Abbé's explanations concerning it, were received in different parts of Europe, with great applause, and have been since deemed an adequate foundation for various theoretical notions of the *practicability* and *utility* of imparting to linen and cotton, a certain *animalization*, to enable them to imbibe and retain colouring matters, more copiously and permanently than they could otherwise do.*

* The following are the Abbé s principal reasonings and conclusions from his experiment, viz. " Il suit de la, que les huiles animales sont plus propres a l'operation, que celles que nous tirons des végétaux en Europe ; mais par quel *mechanisme** *ces* huiles retiennent—elles les parties imperceptibles, qui, dans les excrémens animaux, se joignent aux atomes colorans de la garance ? Il est d'autant plus difficile de l'expliquer, qu'on ne remarque aucune difference sur les fibres, qui ont éte empreintes du savon, tel que je vieus de le decrire, soit que l'on supprime ou non, les excrémens animaux. Cependant cette suppression fait une grande différence pour la couleur, car le coton ne la prend pas, toutes les fois que l'on emploie le sain-doux, sans employer les crottes de brebis ; preuve évidente que les graisses des animaux, ne contiennent point les molécules, avec les quelles la garance a tant d'affinité.

* Every thing at that time was to be explained upon mechanical principles.

It will have been seen, by the opinions which I have delivered on this subject in the preceding chapter, that I am not disposed to deny the efficacy of some animal matters toward enabling linen and cotton to acquire more durable colours in dyeing, than any which we as yet know how to communicate, without them; but this, so far as my experience reaches, is done by some peculiar property, besides that of their animal nature, and only in conjunction with some earthy or metallic basis. Indeed, numerous experiments have convinced me, that if it were practicable, by the application of such matters completely to change the *nature* of linen and cotton, and give them not only the *chemical properties or affinities* of wool, but also

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" S'il m' étoit permis de me livrer à des conjectures, je croirois que toute l'opération se réduit, à dépouiller le sain-doux qui s'est joint aux molécules excrémentielles, de toute sa partie grasse, et qu'il ne reste plus sur les fibres du coton, que la partie terreuse de cette graisse, indissoluble aux alkalis savonneux: mais il est bien difficile de s'en assurer par l'expérience; ici la nature disparoit a nos yeux, ou plutôt elle se voile sous un *mechanisme* si délicat, qu'a peine laisse-telle quelque prise a l'imagination.

" Je me borne donc au fait que je viens d'etablir."

" L'essentielle, avant d'aller plus loin, etoit de *constater le principe*, et de faire vóir *que dans cette espèce de téinture, les atomes colorans se jettent immédiatement sur la substance animale*, et non sur la *terre blanche d'alun*, comme il arive dans la teinture d'Andrinople." See p. 21 and 22 of the volume recently quoted.

the advantage of its porous and tubulous structure, it would still be impossible to make it capable of acquiring, either from madder or the chay root, a colour like that in question, without the aid of some basis or means beyond those stated to have been employed by the Abbé Mazeas in his successful experiment: I have, indeed, repeated that experiment, and made others upon similar principles without success, and I have, therefore, but little difficulty in believing, that in regard to the results of that experiment, he must have been deceived; probably by supposing, unwarrantably, that his colour possessed a much greater degree of stability, than it could have done without other means.

But what are we to think of those who, more recently as well as formerly, have, in their communications, omitted to mention the employment of any preparation of alum in dyeing the Malabar and Coromandel red upon cotton yarn, from the chay root? Did this omission proceed from ignorance* and inattention in the authors of these communications, or from studied concealment in the Indian dyers; or is it more probable that the water employed by them may naturally hold alum

* When persons do not understand the principle, or cause upon which the success of an operation depends, it must always be difficult for them to describe it completely, or without overlooking something of importance.

in solution, and that this fact may have been overlooked, by persons who were not properly sensible of its importance?* That the colouring matter of the chay root does not possess any peculiar property, which could enable it, without alumine, to produce effects which the dyers of Turkey red have found it impossible to obtain from madder without that basis, I am well convinced by a multitude of trials; I have, indeed, found that when cotton had been fully impregnated with oil, the soluble parts of sheep's dung and of gall nuts, its attraction for the colouring matters both of madder and of chay roots, was considerably increased, but not in any degree which could at all warrant a belief of its being practicable, by such means *only*, to produce any colour similar to the Turkey red, and yet, in addition to the omissions in the several accounts already noticed, I have to observe, that there is *no mention of alum* in the communication lately made to the Society of Arts, Manufactures, &c. by Mr. Machlachlan, of the process for "dyeing the beautiful reds of the Coromandel Coast, from chaya root, and the

† Dr. Taylor, Secretary to the Society of Arts, Manufactures, and Commerce, who possesses great theoretical and *practical* knowledge on the subject of dyeing, and was formerly engaged extensively in the dyeing of Turkey red, told me very lately, that the *last* of these suppositions appeared to him to be the most probable.

leaves of cashaw, or cashan;" (see the 22nd volume of their Transactions,) nor in that which was recently made by Mr. Benjamin Heyne, acting Company's Botanist on the Coast of Coromandel, (in a letter) to the Right Hon. Lord Hobart, (now Earl of Buckinghamshire) of the method used by the Malabars, of dyeing a beautiful and lasting red on cotton yarn, with the chay root, &c. of which I was favoured with a copy by Dr. Roxburgh.

This communication by Mr. Heyne, would probably have obtained a greater portion of my confidence, if he had appeared either to have known *more*, or not to have known so much, on the subject; and especially if he had not been so manifestly influenced by the reasonings of Mr. Gren in regard to the supposed *animalization* of the cotton dyed by this method; to which animalization he *exclusively* imputes the stability of this colour, and seems to believe (erroneously) that the first notions of its utility originated with Mr. Gren.

It appears, by Mr. Heyne's account of the Malabar practice, that the cotton yarn is divided into small skeins of only 30 or 40 threads each, and so attached to bamboo sticks, that, when spread, every single thread may be exposed to the powerful rays of the sun; after which, being put into cold water, it is beat and pressed by hands, during half an hour, and then left to steep until it

begins to emit a *putrid smell*, which it will commonly do in that climate at the end of 36 hours; when this happens, the yarn is well washed, then beaten upon a stone, and afterwards exposed to the sun. Mr. Heyne supposes, that the former part of this operation may separate some mucilaginous, gummy, or other vegetable matter, which might obstruct the action or combination of the other matters which are to be subsequently applied and that by the subsequent *beating*, the texture or twistings of the threads must be so loosened as to render each fibre more accessible to these matters.

The next application, and the only one containing animal matter, resembles the grey steep, or *bain bis*, already described; excepting the substitution of a lixivium from the ashes of burnt vegetables, for that of soda, and of the *gingelly* oil* for that of Gallipoli, and, excepting an addition which is made to it, of a liquor called zickey, to be soon described. Mr. Heyne computes that for each pound of yarn, it may be necessary to employ in this steep one pint of oil, two quarts of lye, and half a pint of zickey, with five

* Mr. Heyne says, the Malabar name of the *sesamum orientale*, which affords the gingelly oil, is elloo, and the Gentoo name, noovoo-chittoo; and that the dyers never use it until, by keeping it a year or longer, it becomes *rancid*, and of a *yellow* colour.

or six ounces of sheep's dung. When this mixture is made, the yarn is to be soaked and squeezed in it, for half an hour, then spread out, two or three hours, to dry in the sun; then soaked, and squeezed again, and afterwards spread out to dry, in the same manner, and finally soaked, squeezed, and dried a third time, all in the same day; after which, the cotton is to be put back into the steep, and left to macerate during the night; and in the morning, the three soakings, squeezings, and dryings, of the preceding day, are to be repeated, and at night the cotton is to be again macerated, &c. which treatment is to be continued during ten days; it is, indeed, prolonged by some of the dyers, with a few slight alterations, for a longer term. When the cotton is supposed to have imbibed a sufficient portion of this, which Mr. Heyne considers as being an animalizing mixture, though it contains nothing of an animal nature but the dung of sheep feeding on vegetables, it is to be washed in clean water; and the matters separated from it by this washing, are to be preserved (with the water employed in the washing) for the space of a year, or until the liquor has acquired some degree of ropiness with a putrid smell, when it takes the name of zickey, and is employed, as before mentioned.

After this treatment, the cotton is to be thoroughly wetted, by repeated dippings and squeezings in water, rendered almost as thick as paste,

by a previous admixture of the powdered casa, or casha leaves,* lately mentioned, and afterwards left to soak in this mixture during the night, and being rinced the next morning, it is to be dried in the sun, and afterwards soaked during one night in an aqueous infusion, made with two handfuls of powdered chay roots, and two handfuls of the leaves of the same plant, for each pound of the yarn, and dried in the sun the following day; which soaking and drying is to be repeated the two following nights and days. But on the fourth night, the soaking is to take place in an infusion of the chay *roots*, without the leaves: On the fifth day, some of the powdered casa leaves are to be formed into a paste, by rubbing them with gingelly oil, and this paste is to be mixed with a quantity of powdered chay root in water, and in this the yarn is to be soaked during the night, and dried in the sun the following day: and this soaking and drying is to be repeated three successive nights and days; after which the yarn is to be *dyed* by putting it into warm water, with a sufficient quantity of powdered chay root, and

* Mr. Heyne says, these dyers will never make use of the leaves growing near their own habitations, even though (as sometimes happens) they are obliged to pay unreasonably for those brought from distant situations; and he appears to think there is a considerable difference between the leaves produced on the sea coast and those of more elevated districts.

bringing it gradually to a boiling heat, which is to be continued until the yarn is supposed to have acquired sufficient colour. But if the dyer afterwards thinks it defective, the cotton is again to be soaked in a cold infusion of casa leaves and chay root, powdered, and again boiled with the latter.

This tedious process, of which I have given an account in as *few words* as possible, occupies almost a month, and is said to be also practised, with some unimportant variations, along the Coast of Coromandel, from Cape Comorin to Palliacottah, but to be *unknown in the northern Circars, and in Bengal.* The colour, though not very *bright at first*, because its superfluous and brownish parts are not separated by a brightening process, (as they are in the Turkey red) constantly improves by wearing and washing.

It will have been observed, that no blood is used in dyeing this colour, and that the cotton imbibes a great proportion of its red colouring matter by being repeatedly soaked in the *cold* infusions of powdered chay root. The subsequent *boiling* with more of that root, while it supplies additional colouring matter, probably unites or combines that which had been previously applied more firmly, by giving greater force and energy to the *attractions* of the several matters which are intended to co-operate in producing and fixing the colour; and of these, I am convinced, that alumine, applied in some way or other, *must be one*, though Mr.

Heyne, (who appears to have seen most of the operations described by himself) *distinctly asserts,* that any such addition would be, not only useless, but injurious to the *beauty*, at least, of the colour; an assertion which I know not how to believe, considering that the Turkey red, dyed upon the *aluminous* basis, is at least equal to that of Malabar in *beauty* and permanency. This I know by a skein of very fine *Malabar red cotton yarn*, which I received from Dr. Roxburgh, and which I have compared and tried in various ways with samples of the best Turkey red, dyed in Great Britain and France.

I am, indeed, the more disposed to consider Mr. Heyne's communication as defective in regard to the use of alum, because I find the latter mentioned as equivalent to, and capable of being substituted for the cassa, or allie leaves, in a manuscript account given by Mr. Ram, " of the method of dyeing *red* with the *chay root* in the Guntoor circar;" which manuscript was also put into my hands by Dr. Roxburgh. From this account it appears, that the cotton, after being treated nearly as Mr. Heyne has described, until it is supposed to have sufficiently imbibed the matters imparted by the grey steep, (composed of an alkaline lixivium, gingelly oil, sheep or goat's dung, and zickey) is to be washed in clean tank water, and well dried; and then " half a pucca seer of the powder of allie (cassa) leaves, *or two*

dubs weight of alum," are directed to be put, with a suitable quantity of water, to the cotton: but as the properties of the *allie* leaves, are so very dissimilar to those of alum, that one cannot be supposed to produce the effects, or answer instead of the other, I think it most probable that Mr. Ram's account would have been more correct, and conformable to the practice of the dyers of the Guntoor Circar, if he had mentioned the alum as being employed, not *instead* of the allie leaves, but subsequently to them; which, considering their astringent property, would have been similar to the practice of the Turkey red dyers, who employ the alum steep immediately after that of galls.

A large quantity of chay root was brought to this country about ten years ago, on account of the East India Company. Until this importation, my only experiments with this root had been made upon a small parcel which grew in the garden of the late Mr. East, at Jamaica, and which, from some defect (as I supposed) in the soil or situation where it was produced, afforded me but very little colouring matter.

In consequence, however, of this importation by the India Company, I was abundantly supplied, and through different channels, with chay root for my experiments; but though some parcels of it were better than others, none of them produced effects equal to the expectations which

I had formed in regard to the properties of this root; and I found, also,that of the several dyers and calico printers, to whom samples of it had been sent, no one had succeeded with, or was disposed to adopt the use of it. This want of success led me to suspect that the imported roots had either been defective in quality when shipped, or had afterwards suffered injury, by age, or, more probably, by the warmth and humidity of the places in which they were stowed to be brought to Europe; and this suspicion was afterwards confirmed, by comparing the results of my experiments and examinations with the rules and marks for distinguishing the *good* from the *defective* roots, which had been mentioned by Mr. Heyne, in his letter to Lord Hobart.*

* Mr. Heyne in this letter, after describing the chay root as being not less important for dyeing and calico printing in that part of India, than madder is in Europe, observes, that great care is necessary to ascertain that it is of good quality, and has not been injured by exposure to rain, or by being kept in *damp* situations: of such injury, says he, " a certain sign is, *that a white colour prevails on the inside of the bark, and in its woody part*; as, on the contrary, a *green colour* may be taken for the *surest sign of its being good.*" He adds, that the *Malabar* dyers, in order to ascertain whether the chay roots have been well preserved, mix some of their powder with a little quick lime in water, and if it affords a fine bright red, they deem it to be good; but the *contrary*, if the colour be only a brownish or dull red. That the natives keep the roots with their stems together in large bundles, secluded from rain and damp air;

But having long been anxious to ascertain the properties of a dyeing drug so much celebrated as the chay root, I endeavoured to procure for my experiments some of that which had suffered the *least* of any in the parcels imported by the India Company, which I was the better able to do, because the greater part of that importation had fallen into the hands of one of my particular friends; and I afterwards bestowed no small portion of my time and attention in making what appeared to be the most proper trials therewith: and by these I satisfied myself that the red colour produced by the chay root, in combination with an aluminous basis, not only on wool, but on linen and cotton, resembled very nearly, in its appearance and permanency, that given by madder with the same basis. It did not seem in any instance to excel that of madder, and sometimes appeared less beautiful, and less durable; but this difference when it occurred, might, as I thought, be reasonably attributed to the injury which the chay root had probably suffered in its quality. When applied to calico *printed* with acetite of alumine, the effect was much like that of madder, excepting that the white grounds were less stained.

and avoid pounding the roots until they are wanted for immediate use. Then they are carefully separated from the stalks, their small fibres cut off, and the better parts of the roots farther dried, to facilitate their reduction to powder.

With the solutions of tin, the chay root produced a very *bright* and lasting red on wool; though, like that of madder, it inclined a little too much to the orange; galls employed with the chay root in dyeing wool, made the colour incline still more to the yellow, as well on the tin as the aluminous basis.

The most remarkable difference in the colouring matters of these roots, was that which regarded their effects with the solutions or oxides of iron, which, with chay root, produced nothing *darker* than *drab* colours, either upon wool or cotton.

Woollen cloth boiled with a solution of lapis calaminaris (oxide of zinc) with muriatic acid, and dyed with powdered chay root, took a bright apple green; and, by substituting a diluted nitrate of lead, as the mordant, a bright cinnamon colour was obtained from this root.

By the Turkey red process, the colouring matter of the chay root produced effects so much like those of madder, that I was confirmed in my belief that the means of fixing its colour, as in the Malabar red, must be *substantially* the same as those employed with madder in Europe, for the Turkey red. Broad-cloth, dyed without any basis, obtained from chay root a brownish red, which was, certainly, neither so bright nor durable as that which it imbibes in the same way from madder; for, by a fortnight's exposure to the sun and air, even in winter, it was reduced to a buff colour;

a strong indication of the necessity of an aluminous or other basis, to *raise* and *fix* the colour of chay root, even on a substance by its nature completely *animal.*

In regard to future importations of the chay root to this country, I think they can *never* be adviseable. A large quantity of it was sent to France, about the year 1774, an account of the then French East India Company; of which no beneficial use could be made, by any of those who attempted to employ it, probably, because it had been damaged, like that since imported to this country. It is true, that M. Le Goux de Flaix endeavours to account for this want of success, by supposing, *most erroneously*, that the purpose for which this root is employed in the East Indies, and the only one which it can answer, as he imagines, is *not that of giving colour*, but of *fixing* the colour of *other matters* there employed with it, in dyeing and calico printing. (See Annales des Arts et Manufactures, No. 51.) This error, however, as it rests on no evidence, and is contradicted by the best of testimony, as well as by many known facts, does not deserve any farther notice: and I conclude from the defective quality of these several importations, that this root must be liable to injury from some cause, naturally, and perhaps, unavoidably connected with a voyage from India to Europe. But if it were possible to obviate all injury of this sort, I should still believe, that no profit or benefit could

result from any future importation of chay root to Great Britain. It can produce no effect which may not be as well obtained from madder, and, as I think, more cheaply. The roots, though very small, consist of so great a portion of *tough woody fibres,* yielding little or no colour, that as far I can judge, two pounds thereof will not produce more effect than one of madder; probably not so much; and as it is most liable to be injured by moisture when reduced to powder, the unground roots can alone be imported, and those must occupy so much space, as greatly to augment the expence of freight; and being, moreover, extremely *hard and tough,* the cost of grinding a given weight of them will, at least, be double that of grinding an equal weight of madder roots, and consequently, must augment, in a four-fold degree, that part of the expence of employing this Indian production in Europe.

ARTICLE II.

Galium.

THIS genius of plants belongs, like the preceding, to the natural order of Stellatæ, and consists of forty eight well-ascertained species, whose roots, with perhaps a few exceptions, contain a red colouring matter, very similar in its properties and effects to that of madder; though, when the brown external covering of the root has been

completely separated, the colour which it gives to wool is certainly *brighter* than that of madder, at least upon the aluminous basis.

The several species of the galium most esteemed and employed in dyeing, are, 1st Galium tinctorium. This abounds in the woods of North America, and is called by the French inhabitants of Canada, *tyssa voyane* rouge, and employed by them to dye their cloths red, as it was by the aboriginal Americans, to dye their porcupine-quills, &c. of that colour. I have made some experiments with two small parcels of this root, one of which was brought from Hudson's Bay, and the other from the country of the *Cherokee* Indians, (westward of Carolina) both of which communicated a very bright and lasting red colour to woollen cloth and to calico, with an aluminous basis, and with iron, colours resembling those of madder, upon the latter basis. Broad-cloth, prepared with the nitro-muriate of tin and cream of tartar, as for scarlet, and dyed with these roots, obtained a more lively red colour than that given by them wit h alum.

The roots of this species of galium are of a dark reddish colour, and though nearly two feet in length, are very slender. These, if I do not mistake, are the roots mentioned by du Pratz, (in his history of Louisiana) under the name of *achechy*, as being full of red juice like chicken's blood,

with which, says he, the tribes about the Mississippi give a beautiful red to their feathers, &c.

The Transactions of the Agricultural Society of New York, contain, as I am informed, an experimental Essay on the properties of galium tinctorium, its uses, &c. by Professor Woodhouse, which Essay, I have not been able to procure.

2d. Galium verum; yellow ladies' bedstraw, or cheese renning. Dr. Cuthbert Gordon, about twenty-five years ago, warmly solicited the attention of the Committee of Privy Council for Matters of Trade, &c. to the cultivation and use of this species of galium, not merely as a substitute for madder, but in some degree of cochineal also; alleging that a scarlet colour might be produced from it, which in beauty would almost equal that of cochineal, and surpass it in durability: and, indeed, some specimens of the colour which I have now before me, and which were said by him to have been dyed from this root, are but little inferior to a great part of the scarlets commonly dyed with cochineal. Dr. Gordon, for his exertions on this subject, obtained a small remuneration, (200l.) and some attempts were made by the Committee of the Privy Council to promote the cultivation of this plant; but, I believe, they were not attended with success, and probably the quantity of colouring matter which the roots afford, is not sufficient to compensate the expence of bringing them to a state of maturity, which requires at

least four years. They are covered by a very dark skin or bark, which must be separated, that its brown colour may not injure that of the other part of the root. Like madder and chay root they rapidly absorb moisture, unless secluded from it, and suffer great injury by doing so. The flowering stems of this plant afford a yellow dye, though it is not much esteemed. According to Pennant, Lightfoot, and others, the roots of this species of galium are commonly employed by the people of the highlands, and of some of the islands of Scotland, particularly Jura and Ulot, for dyeing a bright red upon their woollen stuffs. Its colouring matter is placed almost exclusively in the inner bark of the roots, and it seems necessary to employ, at least, three times as much of them as of madder, to produce equal effect. If propagated for dyeing, it should be planted in a very deep loose sandy soil, having some intermixture of marl.

3d. Galium mollugo; or great ladies' bedstraw, commonly called wild madder, and great bastard madder. Its roots are a little larger than those of the former species, and they produce, by dyeing, a red colour equally bright and lasting.

4th. Galium sylvaticum; wood ladies' bedstraw: the rubia sylvatica levis of Bauhine. Its roots dye red, like the preceding.

5th. Galium boreale; cross-leaved ladies' bedstraw: rubia pratensis lævis acuto folio of Bauhine, Pinax 333.

I have made no trials of this root, which is said to afford a more lively and beautiful red than the roots of any other species of galium. Haller says, that in Switzerland the roots are ground with the dust of malt, and afterwards infused in small beer, and that woollen yarn, being first macerated and afterwards boiled in this mixture, acquires a fine red colour: probably alum is employed at the same time, though he does not mention it.

6th. Galium aparine; common rough ladies' bedstraw; cleavers, or goose grass. The roots of this species also dye red, but the colour is less pure and vivid than that of galium boreale; which is, also, the case of several other species of this genus, particularly galium purpureum, or purple ladies' bedstraw, and galium cruciatum, or crosswort.

Most, and probably all, of the species of galium, before mentioned, impart (like madder) a red colour to the bones of animals, with whose food the powdered roots have been mixed.

Very nearly related to galium, and possessing a similar colouring matter, are the roots of several species of the genus *asperula;* woodroof, or woodrowel, particularly asperula arvensis, blue or field wood roof, which Bauhine considered as a species of madder, and also,

Asperula tinctoria; or dyers' woodroof, the roots of which, according to Linnæus, are used for dyeing red instead of madder, particularly by the inhabitants of Gothland.

ART. III.

Morinda Citrifolia, Lin. A Shrub, (sometimes arboreous); the Bancudus small latifolia of Rhumphius; Coda-pilava of Rheede, and of Ray; called Aal, *in Malava, and* Atchy, *in Oude.*

This genus, like those of rubia, oldenlandia, and galium, is included among *rubiaceæ* of Jussieu; but it does not, like the others, appertain to the natural order of stellatæ: and its colouring matter partakes so much of the orange, that it is only by being concentrated and accumulated in the stuffs dyed therewith, that it produces a red colour, always inclining a little to the orange tint. Indeed, one species of this genus, the morinda umbellata, is employed in Cochinchina, and other parts of Asia, as a yellow dye; and the genus itself is so nearly related to that of morus, which contains the dyers' mulberry, (improperly called old fustic) that its name was thereby suggested to Vaillant, and composed from the words *morus indica.*

The colouring matter of the morinda citrifolia, resides chiefly in the bark of the roots of this shrub; and as the smaller branches, or divisions of the root, contain the least proportion of woody fibres, and, consequently, yield most colouring matter, they bear the highest price.

When Mr. Alderman Prinsep returned to this country from India, more than twenty years ago, he favoured me with a box filled with small roots, broken into a coarse powder, and in colour differing not much from madder: to this he gave the name of *aurtch*, adding, that it was "the Bengal substitute for madder; and that, if better pounded, it would answer in the proportion of *three to two* of the latter." He gave me no information concerning the ways or means of employing this substitute in Bengal; but I find in the Asiatic Researches, (vol. iv. p. 35. 4to.) a communication by Wm. Hunter, Esq. respecting this species of morinda, and the red colour dyed with it, in that part of India, from which, and several coroborating circumstances, I am convinced that the roots given to me by Mr. Prinsep are no other than those of morinda citrifolia.*

I lately mentioned that the Malabar and Coromandel red dye from the chay root, was not known to the Bengal dyers; and, so far as I can discover, they supply its place by that which is produced from the roots of this species of morinda.

By Mr. Hunter's account it appears, that the cotton to be dyed by these roots, is first macerated in a lixivium of soda mixed with the oil

* Probably the name of *aurtch*, employed by Mr. Prinsep, has been derived from that of atchy, which the morinda citrifolia bears in the province of *Oude*.

of sesamum, then rinced and dried. It is afterwards soaked in an aqueous infusion of the large *her*, or *har*, (which is the ripe astringent fruit of the terminalia chebula, a species of myrobalan,) and, after the infusion has been moderately squeezed from it, the cotton is exposed to the rays of the sun during four or five days, in which it will acquire a cream colour. It is then macerated in a solution of alum, (made by employing one pound of water, to each ounce of alum in powder,) and after being thoroughly and equally penetrated by this solution, the superfluous part of the latter is to be separated by moderate pressure, and the cotton again exposed four or five days to the sun, that it may be well dried; and this being done, it is rinced in cold water, and again dried. Three gallons and one half of water are then put into a copper dyeing pan, placed over a fire, and the cotton immersed therein, so that it may be equally and thoroughly wetted; this being done, add from one to two seers of *aal* (i. e. the roots of morinda citrifolia,) in powder, (according to the quality of the powder,) having first rubbed and well mixed the latter with the oil of sesamum, at the rate of two ounces for each seer of the powdered roots. Put also into the pan, one eighth of a seer of the flowers of *d'hawry** for each seer of the *aal*; or, instead of

* This vegetable is the lythrum fruticosum of Roxburgh.

these flowers, one ounce and one half of purwas, (a sort of gall nut,) in powder. The cotton and other ingredients, just mentioned, are to be kept over a very moderate fire during three hours, at the end of which, the liquor is made to boil until the colour is sufficiently raised; the cotton being constantly stirred, and frequently lifted above the dyeing *liquor*. If the latter becomes red, it is supposed that the colour of the cotton will be defective, unless a farther portion of the flowers of d'hawry be added. The red colour dyed in this way, is said by Mr. Hunter to be more esteemed for its *great durability* than for its beauty. He adds, that with a basis or solution of iron, these roots dye lasting purple and chocolate colours; that they penetrate three or four feet into the earth; that great quantities of them are sent to Guzerat and the Northern parts of Hindostan.

Presuming that the roots which I received from Mr. Prinsep, as being the Bengal substitute for madder, must be those of the morinda citrifolia, I shall here mention the results of my experiments with them, in dyeing *woollen* and *cotton* stuffs.

To the former, prepared as usual by being boiled with alum and tartar, these roots communicated by dyeing in a moderate heat, as with madder, a bright red colour, inclining a little to the orange tint, which, by subsequent exposure

to the sun, rain, winds, &c. proved to be very durable.

Broad-cloth prepared by being boiled with nitro-muriate of tin and tartar, as for the cochineal scarlet, acquired a very bright colour, but little inferior in vivacity to the colour which would have been produced, if the cloth so prepared had been dyed with cochineal, but partaking too much of the orange to be deemed a scarlet. Indeed, it very much resembled the colour which I lately described as having been produced by the rubia manjit'h upon cloth prepared in the same way; and this colour was also found to be very durable.

Calico, printed with the acetates of alumine and of iron, both separately and mixed, being afterwards cleansed as usual, and dyed with the Bengal substitute, took red, purple, and darker colours, very much like those which would have been produced by madder with the same bases or mordants, and equally durable. With other bases, colours were produced not differing much from those which madder would have produced with the same means. And I am, therefore, induced to believe, that importations of this root, to be employed here instead of madder, might afford profit to the importers, and benefit to the public. There is certainly no danger of its suffering like the chay root, either by a sea voyage, or by long keeping in this country, at least if

proper care be taken of it; the parcel given to me by Mr. Prinsep having now been more than twenty years in my possession, without any perceptible deterioration, though powdered, and never secluded from atmospheric air, even when the latter was unusually damp. Care should, however, be taken previously to bring these roots into a state, in which they will occupy the least possible space, and be liable to the least expence for freight &c.

I may be here allowed, as I hope, *slightly* to notice a few other red colouring matters, which, though they do not strictly appertain to this chapter, cannot be referred to in any other, without greater impropriety.

Of these, the first is the anchusa tinctoria, or dyers' alkanet; the root of which abounds in a dark red colouring matter, readily soluble in alcohol and in oils. It was employed to dye wool by the ancients, as is mentioned by Pliny, Lib. xxii. c. 20. and has been used for the same purpose by the moderns, particularly in France, though the use of it in this way seems to be now generally discarded, that of madder being found much more advantageous. Haussman, indeed, states, in the Ann. de Chimie, tom. 60, that if the colour of this root be extracted by alcohol, and applied by dyeing to silk or cotton which have previously imbibed the aluminous basis, it will communicate a beautiful and sufficiently perma-

nent purple violet colour, (pourpre-violet,) but this menstruum would be too costly in this country. The roots of the anchusa virginica, called puccoon in that part of America, possess a colouring matter nearly similar, and were formerly employed by the savages to paint their naked bodies.

The roots of the sanguinaria canadensis, or Canadian blood root, so called by Morinus, and after him by Dillenius, from the blood-red colour, which the juice of the fresh-gathered root exhibits, (but which changes to an orange by drying,) are sometimes employed by the inhabitants of South Carolina for giving an orange colour to silk and muslins, though it soon fades, and was found, by many experiments which I made with it, incapable of being rendered permanent. This seems, also, to have been called puccoon by the savages there, and was, as is mentioned by Catesby, employed with bear's oil to paint their skins. With a solution of tin it produced a bright orange on silk. It possesses a violent emetic quality.

I received, some years ago, from Dr. Roxburgh, a small parcel of the red powder, which covers the capsules of the rottleria tinctoria, or wassunta-gunda of the telingas, which powder is a noted dyeing drug, especially among the Moors in the East Indies, and forms a considerable branch of commerce from the mountainous

parts of the Circars. The colour of this powder seems to be intermixed with a portion of resinous matter, which renders it but little soluble in water only, but being made soluble by an admixture of soda, I found it afterwards capable of dyeing a very high and bright orange, with alum and with the solutions of tin, which orange colour was sufficiently durable on silk, but less so on cotton.

Barrere, in his Nouvelle relation de la France Equinoctiale, p. 39, mentions a species of convolvulus, growing about the river of Amazons, and called by the Carribbees, kariarou, which yields a pulp as red as vermilion, ("une fæcule aussi rouge que le vermillon d'Espagne,") and which the savages and Portugueze employ to dye their cotton hammocs. He calls it "convolvulus tinctorius folio vitigineo;" I endeavoured, when in Guiana, to procure some of this colouring matter, but without success.

The Danais of Commerson, is a creeping shrub, appertaining to the *rubiaceæ* of Jussieu, which, as we are informed by M. du Petit Thouars, the people of Madagascar employ as a red dye for the cloth which they weave from the thread of the tafia palm; but it has never been in my power to make any experiment with it.

CHAP. V.

Of Brasil, and other Woods, affording red colouring Matters.

"Peragitur progressio coloris rubei a Brasilio ligno, quod et Verzinum dicitur, utrunque enim ipsius ligni nomem deducitur a Provincia Indiæ utriusque nominis, &c."

CANEPARIUS DE ATRAMENTIS, p. 199.

ART. I.

Brasil Wood.

THIS, and most of the woods to which this chapter is appropriated, belong to the genus *cæsalpinia*, so named in honor of Cæsalpinus, the father of the systematic arangement of plants. It is the heart, or central part, of a large Brasilian tree, the cæsalpinia echinata. Other dyeing woods had, however, been previously known under the name of *Brasil;* and, probably, that of the cæsalpinia sappan, to be noticed presently.

It will have been seen by my quotation from *Caneparius*, at the commencement of this chapter, that he supposed, according to an opinion which has long prevailed, and which Berthollet has adopted, (tom. ii. p. 228,) that the wood

under consideration, obtained its name of Brasil, *from* the country where it is indigenous, instead of communicating, *as it certainly did*, this name to that part of South America, which is now distinguished by it.

I have mentioned at p. 400, of my first volume, on the authority of Muratori and Bischoff, "an old charter, or contract, passed in the year 1194, between the cities of Bologna and Ferrara, by which a duty was to be levied in the former of these cities upon the *grana de Brasile*, meaning kermes;" and have stated, on the same authority, that these Brasilian grains, "and also *Brasil wood*, were mentioned in other old charters, particularly one dated in 1198, and another in 1306, under the name of *braxilis*," which, as well as that of *brasilis*, is understood to have been "derived from *bragio*, a *burning coal*, (in French *braise*,*) which was suited to give the best idea of a very bright red, or *flame* colour; and as the sappan wood, which (like indigo, the spices, &c.) might have been obtained from India, through Egypt, Syria, &c. would, whilst the tin basis was unknown, have afforded that colour, with even more brightness than the kermes, it might

* In the original edition of the French Encyclopedia, I find "*brasiller*," mentioned as a verb neuter, and as a "terme de marine," used to signify "les *feux*, & *la lumiere* que jette la mer pendant la nuit."

also, with at least equal propriety, obtain the name of brasilis or braxilis. Certainly the dyeing wood so designated, could not have been an American production, as that quarter of the globe had not then been discovered.

That *red dyeing woods* were commonly called *Brasil* woods, long before this name had been given to the Portuguese territory in South America, may be proved, most unquestionably, by the most accurate and best informed narrator of the events of his own time, Peter Martyr, Secretary to the first (Spanish) Council of the Indies; who, in the fourth chapter of his *first* Decade, addressed to the Cardinal of Arragon, after giving an account of the second voyage of Columbus, (with whom he was intimately acquainted,) to America, (whence the latter had returned to Spain in March, 1495,) states, that not far from the mountains of "*Cibana*," in Hispaniola, "are many great woods, in which are none other trees than Brasil, which the Italians call verzino." And in the next chapter, when giving an account of transactions which occurred at Hispaniola, in the absence of Columbus, (i. e. previous to his third voyage,) Martyr mentions an excursion which Bartholomew Columbus, the Admiral's brother, made to the mountains of Cibana, where, having divided his men "into twenty-five decurions with their Captains, he sent two decurions to the regions of those kings, in whose lands were the

great woods of *Brasile* trees. Inclining towards the left hand they saw the woods, entered into them, and felled the high and precious trees which were to that day untouched. Each of the decurions filled certain island houses, with the trunks of *Brasile*, there to be reserved until the ships came, which should carry them away." I have here given the words of the earliest English translation of Martyr's Decades, by Robert Eden, in *black* letter, not having at this time the Latin original, (which is indeed scarce) in my possession. The second chapter of the first Decade, was finished on the day previous to the calends of May, 1494; but the third and fourth chapters appear not to have been written until the year 1500, about, or a little before, the time when Peter Alvarez Cabral sailed from Portugal with a fleet bound to the East Indies, by the Cape of Good Hope, and unexpectedly discovered the coast of that part of South America, which *nearly one hundred years afterwards* obtained the name of *Brasil;* but to which he then gave that of "*Santa Cruz*," after he had erected a *cross* upon a tree, at a place now called Porto Seguro. It is, therefore, impossible that Peter Martyr could have been led to give the appellation of Brasil to the trees in question, or their wood, from any connection, real or supposed, between them and a part of America, with whose discovery or existence he could not have been acquainted, when he made use of

that appellation. Indeed, the country since named Brasil, is not the only place which received that name from the *dye wood* under consideration; for the harbour now called Yaquimo, in Hispaniola, had been previously called *Brasil*, from the abundance of trees producing that, or a similar, dyeing wood, which grew on the neighbouring mountains; and, accordingly, Ferdinand Columbus, in his history of his father's life, informs us, that as soon as it was known in Spain that the latter, in his third voyage, had discovered Paria, and the country about the Orinoco, he was followed thither by Alonzo de Ojeda, (with whom Americus Vespusius had embarked,) and that, sailing thence to Hispaniola, on the 6th of September, Ojeda put into the port, which the Christians called *Brazil*, and the Indians Yaquimo, designing to take (forcibly) what he could from the Indians, and load with wood and slaves." The wood here meant was the *red* dyeing wood, after which the harbour had been *named*, and the slaves were the peaceable natives, who were intended to be kidnapped or stolen, and sold in Spain.

In the ninth book of his first Decade, P. Martyr gives an account of the voyage which Vincent Pizon and his nephew undertook from Palos, in December, 1499, and in which they sailed from the river Amazons westward, along the coast of Guiana and Paria; and when returning to Spain, in the month of October following,

brought away with them great plenty of cassia fistula, &c. "They found, (says our author,) in some islands about Paria, great woods of Brasil trees, and brought away with them three thousand pounds weight thereof:" "They say," adds he, "that the Brasil of Hispaniola is much better than this to dye cloth with a more fair and durable colour." Probably this, and some other red dyeing woods,* which were soon after brought from different parts of the West Indies, under the name of Brasil, belonged to another species of this genus, the cæsalpinia crista, or to that improperly called cæsalpinia brasiliensis, both of which afford, what is now called, braziletto wood.

For many years the wood, to which the name of Brasil is now strictly and exclusively appropriated, has been monopolized by the government of Portugal, and its exportation from the country which produces it, except for account of that government, has been prohibited under severe penalties. The best of this wood is shipped and sent from Fernambuca, formerly called *Olinda* Pernambuco, and is said to grow chiefly in the captainry, or district of Paraiba. It is called *pao*

* In the fourth chapter of his seventh Decade, P. Martyr mentions, as having been recently brought from the West Indies, "*coccinean* wood, used for dyeing wool, which the Italian calleth *verzin,* and the Spaniard *Brasil.*"

do Brasil by the Portuguese, and *ibirapitanga* by the Aborigines of that country. It is described as a large tree armed, or beset, both on the trunk and branches, with short *spines* or thorns; having leafets elliptic obtuse; racemes simple; and legumes prickly and bivalved, (each containing, according to Valentin, two red shining beans.) It is said to grow exclusively in elevated rocky situations, remote from the sea.*

There is, probably, a variety of this species, which is less an object of the vigilance of government in Brasil, and, therefore, sometimes clandestinely exported; I have several times been requested to make trials of this supposed variety, which had been sold in London as the *true Brasil wood*, smuggled from the place of its growth; and having done so, have invariably found, that though the colour which it produced resembled that of the wood supplied by the government of Portugal, it was greatly deficient in the *quantity*

* Piso confirms this, he says, "In locis mari vicinis non apparet, sed tantum in mediterraneis sylvis, *unde magno labore ad littoralia vehitur*" Brasil, p. 164. Valentin agrees with Piso in this, and adds that they grow widely dispersed among other trees. The medullary part, or heart, is alone used in dyeing, and this bears so small a proportion to the sap, that when the latter is removed, the former, in a tree as large in circumference as a man's body, will be no bigger than his leg. It is red, hard, ponderous, and sparkles in burning.

of its colouring matter, which never exceeded one third of that afforded by the true Brasil wood. How the trees producing this inferior wood is distinguishable from the other, I know not; and, probably, those who are best able, will not be disposed to favour a diffusion of knowledge on the subject. Indeed, it is possible that the difference may depend, in a great degree, on the ages of the trees producing these several woods. Dr. Roxburgh having observed, in regard to the sappan wood, that it is best when taken from the *oldest* trees, and this being also true of logwood.

Water, if copiously employed, and at a boiling heat, may be made to dissolve and extract all the colouring matter of Brasil wood, and, therefore, the practice, which is common among those who grind it, of sprinkling the powder with stale urine (which they call mastering) must be intended to raise and brighten its colour, by the volatile alkali which is thus applied to the powder in question.

There is a general persuasion, founded, as far as I can judge, upon experience, that by making a decoction of Brasil wood, and keeping it two, three, or more months, according to the temperature of the atmosphere, to ferment and become ropy, before it is employed for dyeing, better and more lasting colours may be obtained, than could be produced from a decoction recently made.

Brasil wood does not appear to contain the smallest portion of tanning matter, though the contrary has been asserted by authors of great respectability. I have repeatedly mixed solutions of glue, and of isinglass, with recent decoctions of the genuine wood, but could never detect any coagulation, or precipitation, of gelatine, as resulting from any such mixture.

It is well known, that the beautiful *rose* colour which this wood communicates to water, is made yellow by acids, and purple by the alkalies and alkaline earths; and I may add, that its colour (as Chevreul seems to have first observed) disappears, or is made latent, by being secluded and confined a few days with sulphuretted hydrogene gas, like that of indigo, but probably not by a similar change. I mean an absorption of oxygene, because, as Chevreul also observes, the colour is restored by adding potash, without any admission of oxygene, and because I did not find that a decoction of Brasil wood lost its colour by being mixed, and secluded several weeks in a *close* vessel, (completely filled) with sugar, and an oxide of tin, which was but little oxygenated, and, therefore, would have been capable of rendering indigo colourless.

With solutions of alumine and of tin, employed as mordants, this wood communicates a very lively and beautiful red to wool, silks, linen, and cotton; but unfortunately, its deficient permanency, especially on the latter, renders the

use of this wood much more limited than it would otherwise be.

With solutions of iron the colour of Brasil wood may be darkened so as to produce violet and black colours, of greater permanency than the red, but less durable than similar colours, which are given by cheaper means.

Alum, if put into a decoction of Brasil wood, even after it has been made yellow by an acid, will restore its red colour, precipitating a part of it, at the same time, and the remainder will nearly all subside, if the acid be saturated by the addition of an alkali. It is in this way that an inferior sort of carmine has long been produced,* for painting in water colours, and improving female complexions. The oxide also produces a fine rose-coloured precipitate from a decoction of Brasil wood, even when it has previously been made yellow by an acid.

I have found, by repeated experiments, that galls when employed with Brasil wood for dyeing upon the aluminous basis, have rendered the colour more lasting upon linen or cotton, and this fact seems to have been long known, for in the old book, mentioned at p. 248 of my first volume, it was directed that linen, intended

* Caneparius says, p. 215, "Conficient *laccam* ex Brasilio, Verzinove dicto;" and that they made red Ink "ex ligno Brasilio, sive Verzino."

to be dyed with Brasil wood, should be prepared with *galls* and alum. Arsenic employed with alum, has likewise appeared to me, to render the red colour of this wood more lasting; but I do not recommend this addition, because the use of it is liable to dangerous accidents.

Having boiled broadcloth with sulphate of lime and a decoction of Brasil wood, for the space of one hour, I found it thoroughly dyed of a full crimson, which did not suffer greatly by a month's exposure to the sun, air, &c.

To dye wool or woollen cloth with Brasil wood, upon the aluminous basis, the former is commonly prepared, as directed at pp. 384 and 385 of my first volume; taking care, however, that the proportion of tartar be, to that of alum, only as one to five or six. But as that part of the colouring matter, which attaches and fixes itself most readily to wool or woollen cloth, does not produce the brighest colour, it is the common practice, first to dye some coarser cloth or stuff in the Brasil wood liquor, in order to deprive it of this least estimable part, before the finer cloth undergoes this operation. The liquor so improved, will also give a lively crimson to silk, which has imbibed the aluminous basis by the usual treatment. Calico, which had been printed with the acetate of alumine, and afterwards cleansed with a mixture of cow-dung in water, as is usual for calico printing, being dyed in a de-

coction of Brasil wood, obtained a fine crimson colour on the parts which had imbibed the aluminous basis, and a pale reddish discolouration on that which was *baseless.* Wishing to ascertain whether either the fat or the drying oils would afford any protection to the crimson colour so produced, I applied fine olive oil to some of the spots or figures which had received this colour, and linseed oil to others, and exposed the calico so dyed to the sun and air during ten summer days; at the end of which, I found that the colour which had been covered by linseed oil, was greatly faded, and that which had been covered by olive oil, considerably more injured than the crimson in other parts, to which nothing had been employed; so that both kinds of oil, instead of retarding, had promoted, the decay of this colour.

Broadcloth prepared in a bath of alum and tartar, with about half as much of the muriosulphate of tin as would be required for a cochineal scarlet, and dyed with Brasil wood, acquired a very lively and beautiful colour of a passable durability. The nitro-muriate of tin, employed in the same way, produces nearly similar effects; but, by employing a portion of galls with the Brasil wood and the nitro-muriate of tin, a durable *orange* colour was produced upon woollen cloth.

M. Dambourney asserts, (see Recueil de procedes, &c. sur les Teintures, p. 172) that he had found, by his experiments, the bark of the white

birch (betula alba) to produce very beneficial effects, in fixing the colour of Brasil wood, conjointly with a solution of tin, made by equal parts of nitric and muriatic acids. But for this purpose he employed sixteen pounds of the birch bark to one pound of Brasil wood, which, he says, dyed four pounds of wool, of the colour which formerly was called Venetian scarlet (ecarlate de Venise.) He seems to think this bark equally efficacious in fixing the colours of logwood. I have reason, however, to doubt whether its effects are so considerable as he imagines, and the very great quantity, which he states to be necessary for producing these effects, will probably discourage its use.

As the oxide of tin has so little affinity for linen and cotton, it will hardly be supposed likely to give any considerable stability to the Brasil wood colour on these substances. It is, however, sometimes employed for this purpose, assisted by a large proportion of galls, or of sumach, which last tends less to degrade the colour than galls, and with it, the Brasil wood gives to cotton yarn a sort of scarlet, which, notwithstanding its fugacity, is found to answer for some uses.

A nitro-muriate of bismuth appeared, by my experiments, to be more efficacious than that of tin, for giving stability to the Brasil wood colour, both on wool and cotton, but it made the colour

incline more to a dark crimson or purplish tint, than it does with the tin basis.

The oxides of antimony and of zinc, applied to wool, gave dark brownish reds with this wood, but they were fugitive and of little value, and of still less on cotton.

The nitrate of lead, employed as a mordant with Brasil wood, produced a good bright red upon wool; but it did not prove sufficiently lasting; solutions of copper employed in the same way, produced dark but fugitive browns.

Wool, prepared with a nitrate of lime, and dyed with Brasil wood, obtained a deep orange colour of passable durability; and a lighter orange of less brightness was produced upon wool, by the sulphate of lime; but on silk, the latter produced only a cinnamon colour, though the nitrate of lime produced a deep orange upon this substance. Cotton received no colour from Brasil wood with either of these mordants.

ART. II.

Sappan, or Sampfan, Wood.

THIS is obtained from the cæsalpinia sappan of Lin. a middle-sized tree, more prickly than the former, with leafits oblong-oval, unequal at the sides, obtuse and glabrous; calyx glabrous;

stamina longer than the corols, and upper petal less.—See Roxburgh's Plants of Coromandel, vol. i. t. 16. It is indigenous to Siam, Pegu, the coast of Coromandel, and many parts of the East Indies, and was described by Rumphius, (Amboyna, iv. p. 56.) under the name of lignum sappan, and by Rheede (Hort. Malabar, vi. p. 3.) under that of *tsiapangam :* Linscoten had previously called it sapon. In some parts of Europe the name of sapon, or *sappan*, has been corruptly changed to that of *japan*.

This wood seems to have been very generally employed for dyeing in the greater part of Asia, during many centuries, and to have found its way to Europe some time before the discovery of America ; though very little of it has been lately imported, except by the Dutch.

The colouring matter of this species of cæsalpinia, differs but little from that of Brasil wood in its properties and effects, or in regard to the mordants required to produce these effects ; but there is a considerable difference in regard to the relative quantities of colouring matter which these woods afford ; that of the best sappan amounting, by my experiments, to little more than half as much as may be obtained from an equal weight of the Brasil, and the colour not being quite so bright.

I am informed that some of the trees, affording the true sappan wood, are now growing at the

Isle de France, having been transplanted thither from Siam.

As the bases, or mordants, proper for the sappan wood, and also the ways of using it, very nearly resemble those which are found to be most beneficial with the Brasil wood, they need not be particularly described.

More than twenty years ago, the late Mr. Nathaniel Smith, then Chairman of the Court of Directors of the East India Company, put into my hands parcels of a species of red wood, which had been recently discovered at the Andeman islands; and of another red wood from the coast of Coromandel, with a request, that I would ascertain their properties for dyeing, compared with those of the true sampfan, or sappan, wood, from *Siam*, of which he also gave me a small parcel. The results, however, of my experiments were not favourable to either of the two first of these woods, as their colouring matter was but partially soluble in water, and both, in quantity and quality, appeared to be greatly inferior to that of the wood from Siam. The red wood of the Andeman islands, however, being boiled in water, with a little soda to render its colour more soluble, appeared, in one respect at least, to resemble the lignum nephriticum, as its decoction, viewed by reflected light, exhibited a full *bright blue colour*, whilst, by transmitted light, it was red.

ART. III.

Nicaragua, or Peach Wood, called by the French Bois da Sainte Marthe.

This seems to belong to the genus cæsalpinia, though the species has not, as I believe, been sufficiently ascertained. Sir Hans Sloane, in his Natural History of Jamaica, has mentioned it as growing about *Nicoja*, on the coast of the South Sea, or Pacific Ocean, and being thence brought by the Lake of Nicaragua to the North Sea. It is almost as red and heavy as the true Brasil, but does not commonly afford more than a third part in quantity, of the colour of the latter; and even this is rather less durable and less beautiful than the true Brasil wood colour, though dyed with the same mordants. It seems to be the curaqua, seu Brasilium Hispanorum, of Hernandez, (p. 121,) and is called, (though I know not why) stock-vish-hout, or stock-fish wood, by the Dutch.

The woods sold under the name of Nicaragua, or peach wood, differ greatly in their quality as well as price; one sort being so deficient in colouring matter, that six pounds of it will only dye as much wool or cloth as one pound of Brasil wood, whilst another variety of it, growing principally about the Rio de la Hacha, eastward of Santa Martha, will produce nearly half the effect of an equal quantity of Brasil wood, and sell proportionably dear; and it is this sort which

they distinguish by the name of stock-fish wood. Dampier mentions another variety, called *blood wood*, growing about the gulph of Nicaragua, and similar, as he thinks, to camwood.

The way of employing the Nicaragua wood, and the mordants used with it, differ so little from those which are thought most suitable for Brasil wood, that any particular explanations on this subject would be superfluous.

ART. IV.

Cæsalpinia Brasiliensis, or smooth-leaved Brasiletto.

THIS is the pseudo santalum croceum of Sir Hans Sloane, (Jam. ii. p. 184,) and the first cæsalpinia of Brown, commonly called, Jamaica brasiletto, or Jamaica red wood. It is one of the cheapest and least esteemed of the red dying woods.

ART. V.

CÆSALPINIA crista; the Bahama, or broad-leaved prickly brasiletto, of which Catesby has given a description and figure (Carolina, vol. ii. 51.) He adds, "the inhabitants of the Bahama islands for-

merly got a great part of their subsistence by cutting this wood, but it is now much exhausted." I have mentioned the wood of this and the preceding article as belonging to different species of cæsalpinia, on what is deemed the best authority, but their distinctions do not seem to have been well ascertained, and I think it very probable, that they are but varieties of one species. Both are commonly employed for dyeing inferior and fugitive red colours, upon the aluminous basis.

ART. VI.

Camwood.

THIS was first brought to Europe from Africa by the Portuguese, who called it *pao-gaban*, or *gaban* wood, having found it near the river of that name. Finch afterwards mentioned it as growing near Sierra Leone, and being there called *kambe;* whence, by abreviation, the name of cam, or kam, has been formed. It appears to be the heart of a tree, which bears legumes, and is nearly related to the genus cæsalpinia, and which professor Afzelius has lately made the foundation of a *new* genus, with the name of *tespesia.*

This wood affords a red colouring matter, differing but little from that of the ordinary Nicaragua wood, either in quality or quantity; and it may be employed with similar mordants.

ART. VII.

Barwood.

THIS is another African production, imported subsequently to the former, and principally from Angola. It does not appear to contain any tannin. Upon the aluminous basis, it gives yellowish brown reds to *wool* and cotton, of considerable durability on the former, though rather fugitive on cotton. This colour may be saddened and varied, by employing solutions of iron or copper with it, either alone or conjointly with alum. The dark red, which is commonly seen upon the British imitations of Bandæna, or East India silk handkerchiefs, is commonly produced by the colouring matter of barwood, saddened by sulphate of iron; and being so saddened, it is now very much employed to give dark grounds for *deep blue* colours, dyed with indigo, and thereby produce a saving of the latter. It commonly bears about half the price of camwood. I have not been able to obtain any accurate information concerning the tree which affords this wood. An inferior sort of it is imported from Old Calabar.

Mr. Clarkson has stated, that an African wood vessel, brought home accidentally among her barwood, a small billet of a superior colour to the rest; that one half of it was cut away for expe-

riments, by which "it was found to produce a colour that emulated the *carmine*, and was deemed so valuable in the dyeing trade, that an offer was immediately made of sixty guineas per ton, for any quantity that could be procured." He has added, that the other half of this billet was "sent back to the coast, as a guide to collect more of the same sort;" but with what success, I know not.

ART. VIII.

Red Saunders.

THE wood brought from Coromandel, under this name, (pterocarpus santalinus) is employed to dye lasting reddish brown colours upon wool, though but a small portion of its colouring matter is soluble by water alone; and even when assisted by potash, or soda, the solution is incomplete; this difficulty may, however, be in some degree overcome by employing the rasped wood with sumach, galls, or the rinds of walnuts. Broadcloth, prepared (as usual) with alum and tartar, being boiled in water with equal portions of ground sumach and rasped saunders, was dyed of a very bright and lasting reddish orange. In several experiments, I found a diluted sulphuric acid to act very efficaciously in extracting the colour of this wood.

Vogler gave, as he asserts, a colour to wool almost equal to scarlet, from this wood, after extracting the colouring matter by spirit of wine; but this menstruum would prove too costly in Great Britain for this use.

CHAP. VI.

Of Logwood.

> Or, " what Campeachy's disputable shore
> Copious affords to tinge the thirsty web."
>
> DYER'S FLEECE.

THE tree producing this wood, is the *hæmatoxylon** Campechianum (Lin.), with crooked spinous branches, leaves abruptly pinnate, leafets inversely heart-shaped, and flowers racemed; the latter are succeeded by small flat lanceolate capsules, about two inches long, and containing each five or six small flat seeds. Like the genus cæsalpinia, it belongs to the natural order of lomentaceæ, and the leguminosæ of Jussieu.†

* The name of hæmatoxylon is formed of two Greek words, signifying *blood wood.*

† Both Sloane and Catesby have described and figured this tree, which grows so rapidly, that in four years after the seed has been planted, the stem often acquires its greatest circumference, which is about two feet. Dampier says, " when the old tree is cut, the sap is *white,* and the heart *red*; the last being only used for dyeing, they chip off all the white sap before they carry it on board." It commonly grows, and is supposed to thrive best, in a wet soil, with a large proportion

This tree has been transplanted from Campeachy and Honduras, to most of the West India islands. Sir Hans Sloane mentions Mr. Barham as having brought the seeds from the former of these places, in 1715, to Jamaica, where it now occupies many large tracts of ground, particularly in the neighbourhood of Savanna-la-Mar.

The Spaniards first became acquainted with this wood, and gave it the name of *palo* Campechio, whence it was called *campeche* wood, by some of the first English writers, by whom it was mentioned, particularly Chilton, Parker, and Middleton (in the collections of Hackluit and Purchas.) But in the voyage of the Earl of Cumberland, it

of clay. The bark of the branches, and of the very young trees, is light-coloured and smooth; but that on the stems of the old trees, is rough and dark coloured. Hitherto the bark has been all thrown away, though, from some few experiments which I have made with it, I am convinced it might be usefully and profitably employed in dyeing, though its colouring matter differs greatly from that of the wood. The younger trees are most thorny. Dr. Robertson (Hist. of America, vol. iii. p. 235, 8vo.) says, "the logwood produced on the *West Coast of Yeucatan*, near the town of St. Francis, where the soil is drier, is in quality far superior to that which grows on the marshy grounds, where the English are settled." Dr. Robertson has here adopted an opinion, which the Spaniards have endeavoured to propagate, in order that the logwood which, since the peace of 1783, they have allowed to be imported, free of duty, from *Campeachy*, might obtain a preference in the market, over that of *Honduras*, cut by the English; but I do not find it to be well founded.

was soon after mentioned under the name of *logwood*, which name seems to have prevailed in this country over the former, as that of bois d'Inde* has among the French, over the appellation of bois de Campeche, which they also first gave it.

Logwood seems to have been first brought to England, soon after the accession of Queen Elizabeth, but the various and beautiful colours dyed from it, proved to be so fugacious, that a general outcry against its use was soon raised, and an act of parliament was passed in the 23d year of her reign, which prohibited the use of it as a dye, under severe penalties; and not only authorized, but directed the *burning* of it, in whatever hands it might be found within the realm; and though this wood was afterwards sometimes clandestinely used, (under the feigned name of blackwood,) it continued subject to this prohibition for nearly one hundred years, or until the passing of the act of the 13th and 14th of Charles the Second; the preamble of which declares, that

* This name of *bois d'Inde*, seems to have misled Berthollet to suppose, (tom. ii. p. 243) that the Jamaica pepper, pimento, or allspice, (obtained from the myrtus pimenta), and the logwood, were produced by the *same tree*; Dutertre, Rochefort, and others, having early distinguished that species of myrtle, or, perhaps, more strictly, the *myrtus acris*, by the name of *bois d'Inde*, which it still bears at Martinico, and other French West India islands.

"the ingenious industry of modern times, hath taught the dyers of England the art of fixing the colours made of *logwood, alias blackwood*, so as that, by experience, they are found as lasting as the colours made with *any other sort of dyeing wood whatsoever*;" and on this ground it repeals so much of the statute of Elizabeth as related to logwood, and gives permission to import and use it for dyeing. Probably, the solicitude of the dyers to obtain this permission, induced them to pretend that their industry had done much more than it really had, in fixing the colours of logwood; most of which, even at this time, are notoriously deficient in regard to their durability.

Six quarts of distilled boiling water, may be made to extract nearly all the colouring matter of one pound of logwood properly chipped, and when so extracted, the decoction will be yellow, with a sweetish taste, and will contain, in addition to the colouring matter, a volatile oil, with small portions of lime and potash, in union with acetic acid, besides some other matters of no importance, in regard to its effects in dyeing. Tannin has been generally considered as one of the constituents of an aqueous extract of logwood, but without reason, as the infusion or decoction when recently made, does not coagulate or precipitate a solution either of glue or of isin-

glass; and the appearance of such precipitation, which is sometimes produced, results from a subsequent absorption of oxygene, for which the colouring matter of logwood has, whilst moist, a strong attraction.

If the decoction be made with common, instead of distilled water, it will exhibit not a *yellow*, or an orange, but a full red or dark blood colour, by reason of either the selenite, or the calcareous earth which such water generally contains; but by adding to it sulphuric, nitric, or muriatic acid, the yellow will be restored, and a subsequent addition of any of the alkalies, in a proportion sufficient to supersaturate the acid, will re-produce the purple colour.

When logwood is of good quality, it will yield from one fifteenth to one twentieth of its weight of *pure colouring matter*, which will be soluble in alcohol and in water, if the decoction, after being made, has been speedily evaporated to a dry state by fire; but if an interval of several weeks is allowed previously to intervene, or if the evaporation be slowly performed, by exposing the decoction to the sun and air, even in summer, or in a hot climate, the colouring matter will absorb and combine with a large proportion of oxygene, and become, in a great degree, insoluble by water, and the colours dyed from it will prove much more *fugitive* than those produced by the decoc-

tion when recently made.* A circumstance in which it differs greatly from the colouring matter of Brasil wood; which last, probably might, with greater advantage than almost any other, be brought into the form of an extract, (for the use of dyers) at the place of its growth, to diminish or obviate the expence of transporting the wood to a sea port, and its subsequent freight to Europe. This strong attraction of the colouring matter of logwood for oxygene, may, perhaps, be a cause of the want of permanency in the colours dyed with it, though we find an equal want of permanency in those obtained from the Brasil wood, whose colouring matter combines but slowly with oxygene, and is benefited rather than injured by

* I found this to be the case of a large parcel of an extract of logwood, which had been prepared in the West Indies, merely by exposing an infusion or decoction of the wood to the sun's rays; it had a fine bright glossy aspect, produced by very small crystals; but a large proportion of it was nearly insoluble by water, and the colours dyed with it were uncommonly fugacious.

Having formerly attempted to substitute the dry extracts of various dyeing drugs, for the drugs in their natural state, in order to diminish the expence of freight, &c. and such attempts having, in almost every instance, been attended with disappointment and loss, by reason of the changes to which colouring matters are liable, by the operations necessary for their extraction and evaporation, it becomes me to recommend caution to those who may be disposed to engage in similar undertakings.

such combination, as is indeed the case of many other colouring matters.*

By adding a sufficient portion of alum to a decoction of logwood, the colouring matter may be *all* made to unite with the alumine, and form a purple or reddish violet compound, separable by the filter so completely, that the water will

* M. Chevreul supposes, that the extract of logwood contains *two sorts* of colouring matter, one, which he calls hæmatine, which is susceptible of crystallization, and soluble both by water and by alcohol, giving them a reddish orange colour, and the other denominated by him, "matiere d'un rouge maron," which is not soluble by water. This last he considers as possessing most of the properties of those vegetables which are called astringent, and especially that of causing a precipitation of gelatine. I am persuaded, however, that this insoluble matter, which occurs only after the colouring matter has been evaporated to dryness, is merely the product of a combination of oxygene, with a portion of that which he calls hæmatine. I have found repeatedly that a decoction of logwood, after being kept five or six weeks in hot weather, lost the sweetness, and acquired the very properties which he ascribes to his "matiere d'un rouge maron," including that of precipitating a solution of isinglass. But this precipitate differs from that produced by the tanning principle, because *it is soluble in boiling water*, which that of *tannin is not*, and this single fact proves, that the precipitation *which does not take place with a recent decoction* of logwood, results from a subsequent change, and a newly-acquired property, differing essentially from that of the tanning principle. For the rest, M. Chevreul admits, that the supposed two sorts of colouring matter are both attracted by the same bases, and applicable in dyeing with the same mordants. See Ann. de Chimie. tom. 81 and 82.

run from it colourless. When not filtered, a great part of the compound will subside, but not the whole, unless an alkali be added. By employing a sulphate of iron instead of alum, a similar combination will take place, and a blueish black colour will be thereby produced. All the solutions of tin produce purple or violet colours with the decoction of logwood, and a complete precipitation of the colouring matter. Solutions of the other metals and earthy bases will also combine with the colouring matter of logwood in different proportions, and with different degrees of affinity, producing various colours and precipitates, to be noticed hereafter. Sulphate of copper added to the decoction of logwood, gives it a purplish blue colour; sulphate of pure zinc added to a similar decoction, produces a dark purple; nitro-muriate of gold, an orange; muriate of quicksilver, an orange red; muriate of antimony, a beautiful crimson; acetate of lead, a garter blue; arseniate of potash, a deep yellow; muriate of barytes, a reddish purple; nitrate of barytes, a brownish purple; strontia earth, a violet; sulphate of magnesia, a purple; muriate of magnesia, a yellow; sulphate of lime, a purple; and muriate of lime, a violet purple. These effects show that the tingent matter of logwood, is capable of producing, with different mordants or bases, almost all the possible varieties of colour.

Sulphuretted hydrogene gas, produces a disap-

pearance of the logwood colour, like that which it occasions to the colour of Brasil wood, and, undoubtedly, in the same way, i. e. merely by combining with it, and not by any deoxygenating effect.

Wool dyed with a decoction of logwood in hard water, obtained a purple colour, which, by exposure to the sun and air, speedily changed to a drab colour; and this last afterwards manifested considerable stability.

Chips of logwood being put into water, acidulated by sulphuric acid, and boiled therein, produced a brownish yellow decoction; and wool dyed therewith obtained a strong yellowish bright snuff colour, which, being exposed to sun and air during five weeks, manifested considerable stability.

Nitric acid being mixed with a decoction of logwood, produced a fine bright yellow. But this, by boiling, gradually became a yellowish brown, and communicated that colour to wool dyed therein; which being sufficiently exposed in the open air, proved to be a lasting colour.

Woollen cloth being boiled during one hour in water, with a suitable portion of sulphate of lime, and afterwards dyed with logwood, acquired a full and bright, though brownish, orange, which proved lasting.

Cloth boiled with a decoction of logwood in

water, slightly acidulated by muriatic acid, took a brownish yellow colour.

Cloth boiled with muriate of lime, and dyed with logwood, took a brownish orange colour, which, however, did not prove sufficiently durable.

Wool dyed with logwood and sulphate of magnesia, received a yellow colour, but it proved very fugitive.

Woollen cloth prepared with alum and tartar, as usual, being dyed with logwood, obtained a bright violet colour, which, by adding a little muriatic acid to the dyeing liquor, may, as I have found, be made to incline more to the red or purple, but neither of these colours have the desired stability; though the former is not unfrequently employed.

The best and least fugitive of the purple or violet colours obtained from logwood, are produced by mordants principally composed of solutions of tin: one of these became very fashionable in France, about thirty years ago, under the name of *prune de Monsieur;* and being then resident at Paris, I wore a coat of this colour, without having had any reason to complain of it as being fugitive. Of the invention and composition of this colour, an account given by M. Descroizilles, (a chemist at Rouen,) to M. Berthollet, was published by the latter, in the first edition of his Elements, &c. from which it ap-

pears, that M. Giros de Gentilly was the first who attempted successfully in France, to introduce the dyeing with logwood and a solution of tin. His first trials were made at the dye-house of Messrs. Petou and Frigard; but he suffered so much to transpire, respecting the composition of his mordant, that M. Decroizilles was soon able to produce a tolerable imitation of it, by making a solution of tin with sulphuric acid, to which he added muriate of soda (sea salt) with acidulous tartrite of potash and sulphate of copper; and this composition answered so well, that M. Giros was induced to form a partnership with M. Decroizilles, to obviate the loss which was likely to result from a competition with him. When this association had taken place, M. Giros taught his new associate a more convenient method of preparing the mordant in question, which was by dissolving the tin in a mixture of sulphuric acid and sea salt, with a suitable proportion of water, to which the tartrite of potash and sulphate of copper in powder were added afterwards. Of this mordant they made at the rate of 1500 quarts daily, in a single leaden vessel; and continued to prepare and sell this composition with great profit, (at 30 sols the pound,) during three years, after which, their sales gradually decreased, until they thought it proper wholly to relinquish the undertaking; the indiscretion of M.Giros, concerning the composition of his

mordant, having produced other imitators, whose compositions, though at first defective, were afterwards preferred to that of the original inventor.

To dye unspun wool with this mordant, the latter was employed in the proportion of one third of the weight of the wool, but for cloth or woollen stuffs one fifth was deemed sufficient; and being mixed in a tin dyeing pan or vessel, properly supplied with water, the wool or cloth was made to imbibe the mordant, by the usual treatment during two hours, and being afterwards rinced, it was dyed in a fresh bath, with logwood; but as the latter, if employed alone, would produce a violet colour, a portion of Brasil wood was added, to make it partake more of the red, and afford that which was called *prune de Monsieur*.

This colour was, indeed, liable to some alteration, if sent to the fulling mill, by the soap and urine there employed; but the alteration was afterwards easily overcome, and the proper colour restored by passing the cloth or stuff through warm water, slightly acidulated by sulphuric acid.

M. Decroizilles asserts, that wool dyed with this mordant was susceptible of being spun with greater evenness, and extension or fineness, than wool dyed with alum; that an omission of the

sulphate of copper rendered the fibres of the wool harsh, and impoverished the colour.

M. Berthollet supposes, that in this composition the sea salt was decomposed by the sulphuric acid, and that the muriatic acid being set at liberty dissolved the tin, of which a part was afterwards precipitated by the acid of tartar. That the oxide of copper formed a blue, with a part of the colouring matter of the logwood, and the oxide of tin a violet with the remaining part, and a red with that of the Brasil wood.

Before the commencement of M. Decroizille's partnership with M. Giros, I had begun to occupy myself with experiments for fixing the colours of logwood and Brasil wood by different solutions of tin, and I have since, at various times, renewed and repeated these experiments with considerable success. I had, at a very early period, discovered the highly important influence of tartar in giving stability to the beautiful yellow produced upon wool or woollen stuffs from the quercitron bark, by solutions of tin, and I was induced, by that discovery, to try the effect of tartar with the basis of tin, in fixing the logwood purple, or violet colour, upon the same stuffs, and I have repeatedly found it more efficacious with that basis, than any other means for enabling this colour to resist the impressions of sun and air. I am, indeed, persuaded that the principal merit of the mordant employed by M. de Giros, results

from the tartar which it contains conjointly with the tin. The sulphate of copper may, indeed, contribute to obviate the harshness which is commonly given to wool by the oxide of tin, and may give a particular tone to the colour; but it certainly cannot render it more durable than it would be with the oxide of tin and tartar in suitable proportions; and if a full proportion of the latter be employed, any of the solutions of tin will, I think, answer the purpose; though the murio-sulphate, as being cheapest, may deserve a preference.

M. Dambourney, who, (as I lately mentioned) has represented the bark of the white birch, betula alba, to be highly efficacious in fixing the colour of Brasil wood, with a nitro-muriate of tin, ascribes to it a similar effect in regard to the colour of logwood, with the same basis; adding, that it moreover changes the colour of the latter to a blood red.

With nitro-muriate of bismuth, employed as a mordant upon wool, logwood produced a bluish violet colour, which being condensed by a protracted boiling, became a very full and durable black.

Wool prepared with sulphate of zinc, and dyed with logwood, obtained a violet colour, which proved fugitive.

Wool, prepared with muriate of antimony and dyed with logwood, became of a snuff colour, which was tolerably permanent.

Wool and broadcloth, prepared by boiling with a diluted nitrate of lead, being afterwards dyed with logwood, obtained a deep blue colour, which soon faded by exposure to the sun and air;—nearly similar effects were produced by substituting the acetate, for the nitrate, of lead.

Wool or cloth, dyed with logwood, and either sulphate of copper or verdigrise, obtains a blue colour, which is, however, neither bright nor durable, though the cheapness of the matters producing it, has caused the use of it to be very frequently and generally adopted; sometimes for stuffs of little value, and at others, to give more fulness or intensity to the blue from indigo, and produce a saving of the latter. Indeed, the excessively high price at which indigo has been sold upon the continent of Europe for several years last past, has there, according to my information, occasioned a very general substitution of logwood, for the purpose just mentioned, and parcularly in France.

To produce the logwood blue, Pœrner recommends half as much sulphate of copper as of the logwood, to be employed; but from the results of my experiments, I conclude that a smaller proportion of the former will suffice. The blue dyed by these means commonly inclines to a greenish tint, perhaps because the oxide of copper becomes green, by a farther absorption of oxygene or of carbonic acid.

Broadcloth dyed with logwood, and one-fifth of its weight of sulphate of copper, and half as much lime, acquired a dark greenish blue, which, after one month's exposure to sun and air, manifested more stability than the blue commonly dyed from logwood. By substituting cream of tartar for the lime, a dark and lasting tobacco brown was produced.

The greatest consumption of logwood results from its use in the dyeing of *black*, especially on wool and woollen cloths or stuffs; but this use of it will be particularly noticed in a subsequent chapter, which I shall appropriate to that colour.

In regard to silk, logwood (besides the black) is employed to give it a violet colour, after it has been alumed as usual; and it is moreover employed as lately mentioned, to give it the colour, which in France is called prune de monsieur. To produce this colour, however, Fabroni has recommended a mordant, prepared by combining the muriate of tin with sulphate of copper and tartar, and employing a small proportion of galls, or of alder bark, with the logwood, in the dyeing liquor.

Berthollet has observed, that silks which had been impregnated with solutions of tin at different degrees of oxidation, being afterwards dyed with logwood, he found that the best effects were produced on those to which tin, the *least* oxygenated, had been applied.

The colouring matter of logwood, has so much less affinity for linen or cotton, than for wool, that it will not attach itself to either of them without the aid of some earthy or metallic basis: but with some of these bases they may be made to receive from it colours nearly resembling those which wool obtains by the same means, excepting the circumstance of their being generally a little more fugitive on the former than upon wool: but this defect may be, in a considerable degree, obviated, by employing a portion of galls with the logwood.

I have attempted, at different times, to give some tolerable degree of permanency to the colouring matter of logwood, applied *topically*, or prosubstantively, to calico, in combination with almost all the known mordants or bases; and, on looking over the notes which I made of my different experiments, the following results seem to be most worthy of notice.

A strong decoction, containing the colouring matter of one pound of logwood, being placed over the fire with half a pound of alum in powder, and gum of Senegal, sufficient to thicken it properly, and these being dissolved and well mixed, and the mixture being applied topically by the pencil to calico, a bright, though darkish, purple colour was produced, which resisted several washings, and a fortnight's exposure to the weather, without much injury. By substituting the ace-

tate of alumine for common alum, effects a little better were produced.

By substituting the muriate, nitro-muriate, and murio-sulphate of tin, for alum, brighter colours were produced, which resisted the action of soap and strong French vinegar, and were not much hurt by several weeks exposure to the sun and air. Phosphate of tin, employed in the same way, produced a bright red colour.

The nitro-muriate of cobalt, employed in the same way, produced with logwood a bluish purple, a little more fugitive than the preceding. Nitro-muriate of antimony, employed in the same way, produced a colour nearly similar to the last.

The nitrates of silver, lead, and zinc, all produced purple or violet colours, but they were more fugitive than those with solutions of tin. The nitro-muriate of nickle, produced with logwood a glossy bright colour, like that of Vigonia wool.

The nitrate of copper, being partly neutralized by ammonia, produced, with the decotion of logwood, a dark blue of considerable durability. A brighter blue, and more useful for topical application, may, however, be obtained, by substituting the sulphate of copper, and partially neutralizing its acid, either by ammonia, potash, or soda, or which is, perhaps, better, by an ammoniate of copper, as formerly mentioned. I have already noticed, at pp. 213 and 214 of this

volume, the good effects of this logwood blue, in combination with a prosubstantive yellow from quercitron bark, in producing a green colour for topical application.

In my arrangement of the adjective colouring matters, I thought it most natural, first to notice the three simple or primitive ones, from which all the others may be compounded, and to begin with the yellow, as being the least removed from white, then proceed to the red, and afterwards to the blue; and it was from a regard to the property which logwood possesses, of producing a *blue* colour with the basis of copper and that of lead, that I have been induced to place it subsequently to the Brasil, and other woods affording *red* colouring matters. This, then, would be the proper place for me to mention any other adjective colouring matters, capable of producing the *blue*, if any such were known, and ascertained to be worthy of being employed by the dyers of Europe. But this, I believe, is not the case. Loureiro has, indeed, mentioned (tom. i. p. 241) the polygonium tinctorium, a perennial plant, growing about Canton, in China, as being employed to dye a fine blue and green, "ad tingendas telas pulchro colore cæruleo aut viridi;" and Thunberg mentions the people of Japan as cultivating, for the same purpose, three other species of polygonium, viz. p. chinense, p. barbatum.

and p. aviculare. But with what bases or mordants these are employed, we are not informed.

Brown, also, in his History of Jamaica, p. 143, mentions the randia aculeata, (now considered as a species of *gardenia*) called Indigo-berry on that island, as affording berries which, when ripe, "stain paper or linen of a *fine fixed blue colour*, which stands either soap or acids." I lately requested my son (now in Jamaica) to send me some of these berries, which he promised to do when the season in which they become ripe should arrive; but not having as yet received any of them, I can add nothing from my own knowledge concerning their use. The wood of the guilandina moringa, or horse-radish tree, and the roots of mercurialis perennis, or dog's mercury, are also said to yield a blue colour; but in the latter at least, it probably has no stability. The bark of the fraxinus excelsior, and the berries of the empetrum nigrum, or black-berried heath, are also said to produce a blue colour, by Jorlin (in a paper, contained in the Amœnitat. Academiæ.)

CHAP. VII.

Of Vegetables affording adjective Brown, and other mixed colouring Matters; including the Fawn, or Fauve Colour of the French.

"Un Physicien qui veut prendre quelque connoissance de l'art de la teinture, est, pour ainsi dire effrayé par la multitude des objets nouveaux que cet art lui presente."

HELLOT. ART DE LA TEINTURE DES LAINES, &c.—*Preface.*

ART. I.

Of the Bark of the Rhizophora Mangle, or Mangrove Tree.

THIS is one of three vegetable colouring matters, of which, in consequence of my discovery of their properties, the use was exclusively vested in me for a term of years, by an act of parliament, as lately mentioned; and the tree producing it grows abundantly on nearly all the sea-coasts between the tropics, *round the globe*, and is eminently remarkable for the singularity of its propagation, not only by seeds, which *germinate* downward several inches, while actually adhering to the branches of the tree,* but also by a great

* Whence its generic name of rhizophora, from two Greek words, which signify root bearing.

number of long round appendices, which, like ropes of different lengths, constantly shoot down from the under sides of most of the branches to the earth, and taking root in the mud, each becomes at first a fulcrum or prop, to support the parent tree against the impetus of the tides and waves of the ocean, and afterwards forms the stem of another tree, which propagates itself in like manner; so that impassable forests are formed, extending many leagues, and nearly all the trees composing it are connected with each other, either by their branches or their roots, of which many, by extending horizontally upon the surface of the earth, arrest and accumulate great masses of earthy and vegetable matters, and thus enable the land constantly to encroach upon the sea, and produce that vast extent of *alluvial* grounds which has been formed within the tropics.

Oviedo, Clusius, De Laet, and other early writers, have mentioned this tree by the name of mangle, which it bore among the natives of Hispaniola; Linschoten gave it the name of arbor de raiz; and Rochefort, that of paretuvier, or paletuvier, which it retains among the French; whilst the Dutch call it, *duizen-beenen*, or thousand legs, from its numerous props or supporters.

There are two varieties of this species of rhizophora, one of which is called the red, and the other the *purple or violet* mangrove; and the

barks of both are nearly half an inch thick, of a reddish brown colour, and replete with colouring matter and *tannin*; both of which may be nearly all extracted by water employed in a sufficient quantity.

Wool, or woollen cloth, prepared as usual with alum and tartar, and dyed with only one-twentieth of its weight of powdered mangrove bark, acqu re sa bright, full, and lasting annotta, or reddish, though somewhat brown orange colour. The solutions of tin, employed as mordants, do not considerably raise or improve the colour of this bark upon wool; though they produce what Dambourney calls, "un mordoré solide."

By substituting the sulphate of iron for alum, wool or cloth will obtain from the mangrove bark, a lasting chocolate brown colour, much darker than the same means will produce upon linen or cotton; and by employing with the sulphate of iron, one-sixth of its weight of carbonate of lime, a very dark and durable drab, or slate, colour will be produced. Sulphate of copper, instead of sulphate of iron, produces, with the same means, a permanent cinnamon brown.

The natural colour of the mangrove bark, or that which it communicates to linen and cotton upon the aluminous basis, is a kind of salmon, or reddish nankin colour, for which it has hitherto been chiefly employed in this country, particularly at Manchester. Probably the cheapest and best mordant for this colour is made by dissolving

eight pounds of alum with one pound of clean chalk or whiting, in six gallons of water; in which, after the solution is effected, the cotton may be soaked twelve hours, then dried, and afterwards dipped into lime water; drying it again, and then soaking it a second time, for about five minutes, in the solution of alum; after which, being well dried and moderately rinced, it may be dyed with about one-twentieth of its weight of the mangrove bark in powder, adding a little when the colour is sufficiently raised.

By substituting the sulphates of iron and copper, as mordants, as well as by mixing them with alum, a great variety of brown, olive, and drab colours may be cheaply dyed from the mangrove bark, upon fustians, cotton, velvets, &c. which will prove more lasting, and much less susceptible of accidental spots and discolourations than similar colours, commonly dyed from the morus tinctoria, &c.

The mangrove bark may be employed by the calico printers for dyeing pieces printed with the acetates of alumine and of iron, upon which it will produce reddish orange and slate colours, without considerably staining the white grounds. This bark will also afford several prosubstantive colours, applicable by the pencil, and of considerable durability.

One of these, a salmon or reddish cinnamon colour, may be made by mixing a very strong decoction of the mangrove bark, with the acetate

of alumine, and afterwards thickening the mixture as usual; and this may be improved by adding to it a little nitro-muriate of tin; or which is better, a murio-tartrite of that metal.

A similar decoction of this bark, mixed with the acetate of iron, will produce a lasting prosubstantive dark drab, or slate, colour.

ART. II.

The Rhizophora Gymnorhiza,

Is another species of this genus, producing very large trees, which cover an immense tract of sea-coast along the southern shores of Cochin-china and Cambodia, as well as in the Straits of Malacca; and is supported by numerous and widely-spreading arcuated roots, which are generally overflowed by the tide at high water. Lourciro says, the thick reddish brown bark of this tree is highly useful in dyeing rufous, or chesnut colours, which are easily converted to black, by alternately dipping the cloth (probably cotton) into a decoction of the bark, and then into a mixture of dark brown mud and water, then drying and repeating the dippings, until the desired colour is obtained;* and this black he re-

* "Utilissimus est ad tingendos telas colore rufo vel castaneo; qui facile in nigrum mutatur, si alternis vicibus immergantur telæ cœno fusco aqua diluto," &c.—Cochin-china, tom. i. p. 297.

presents as permanent. The mud employed for this purpose, doubtless, contains an oxide of iron; but if this will render the colour black, there must, in that respect, be a considerable difference between the colouring matters of this, and the former species.

ART. III.

The Bark of the Mahogany Tree, (Sweitenia Mahogani,)

POSSESSES colouring matter, so nearly similar to that of the mangrove, that no additional explanation can be wanted respecting the effects which it produces with different mordants, or the methods of applying it for dyeing, excepting only the circumstance of its affording about one-third less of colouring matter, than an equal weight of mangrove bark.

ART. IV.

The Bark of the Acer Rubrum, or Scarlet Flowering Maple of North America, (described and figured by Catesby, tom. i. p. 62.)

PRODUCES a very lasting cinnamon colour with the aluminous basis, not only on wool but on cotton; and with the sulphate, or the acetate of

iron, it communicates to both, a more *intense, pure,* and *perfect black, than even galls,* or any other vegetable matter within my knowledge, and it has the advantage, in calico printing, of not only not staining the white grounds, but of obviating (like the d'howah, lately mentioned) the stains which some other colouring matters would produce without it. The leaves of this species of maple produce effects nearly similar to the bark.

ART. V.

American Oaks.

I HAVE made experiments with nearly all the twenty species of American oaks, described and figured by the elder Michaux, and they have all, excepting the quercitron oak, and some few varieties possessing similar properties, appeared to contain large proportions of a colouring matter which, with the aluminous basis, produces cinnamon browns, and with that of iron, blacks, more or less perfect.

ART. VI.

Pinus Abies Americana, or Hemlock Spruce.

THE bark of this tree, which is employed in Nova Scotia to tan leather, affords a colouring matter

which, with an aluminous basis, produces a lasting bright reddish brown colour upon wool, and a nankin colour on cotton, which, however, on the latter, is a little deficient in durability. With either sulphate, or acetate of iron, this bark produces dark drab and slate colours; but not a black.

ART. VII.

Juglans oblonga Alba, or North American White Walnut, commonly Butternut.

In Dr. Birch's History of the Royal Society, it is stated that this learned body received, on the 10th of February, 1669-70, from Mr. Winthrop, one of the Fellows, some stuff, manufactured in New England from a mixture of cotton and wool, and sent by him "to shew the colour, which was only dyed with the bark of a kind of wallnut tree, called by the planters butternut tree, the kernel of that sort of walnut being very oily, whence they are called butternuts. They dyed it only with a decoction of that bark, without alum or copperas."

I have been, from a very early part of my life, acquainted with this tree, and have made numerous experiments with its bark, the colouring matter of which, has, indeed, so much affinity with wool, that, without any mordant or basis, a decoction of it will dye woollen stuffs of a du-

rable tobacco brown, which may, however, be improved, both in brightness and permanency, by an aluminous basis; and this last is necessary to fix this colour upon linen or cotton. With either the sulphate or acetate of iron, this bark communicates to wool, linen, and cotton, a strong and lasting black colour, and calicoes printed with the acetates of alumine and of iron, separately, and also mixed, being dyed with this bark, will receive various shades of brown, drab, and black colours, sufficiently permanent, and without any stain or discolouration of the white grounds; a decoction of this bark, in which a little gum arabic had been dissolved, having, in the course of my experiments, been mixed with a solution of iron by nitric acid, the whole was *instantaneously converted into a solid blackish mass*, which required considerable trituration in a glass mortar, with hot water to divide and render it soluble again. I repeated the experiment afterwards, with a similar effect; though nothing like it was produced by any other metallic nitrate, of which I mixed several with a similar decoction of this bark. The rinds of the nuts of this tree possess the same colouring matter as the bark; and both afford an extract, which is much esteemed in the United States of America as a mild cathartic.

ARTICLE. VIII.

The Juglans Nigra Oblonga, or Oblong-fruited Black Walnut of North America,

AFFORDS, by its bark, and the rinds of its nuts, a dark brown colouring matter, which, on the aluminous basis, communicates to wool and cotton a sort of durable tobacco, or chesnut brown; and with solutions of iron, a brown considerably darker; my experiments, however, with this vegetable, have been but few. Dambourney says, that with a nitro-muriate of bismuth it gave to wool a very lasting puce, or flea colour.

ART. IX.

The Juglans Regia, or Common Walnut,

AFFORDS in the rinds of its nuts a colouring matter, which, though naturally almost limpid, changes to a dark brown by exposure to atmospheric air, whence it probably absorbs oxygene; of this change proofs are in the autumn frequently seen, upon the hands of those who employ themselves in separating these rinds from the nuts. Braconnot, from a series of experiments upon these rinds, infers, that they contain starch, and an acrid bitter substance, which, by combining with oxygene, becomes carbonaceous; also malic acid, citric

acid, tannin, phosphate of lime, oxalate of lime, and potash. He says, the recent juice being filtered, exhibits an ambour colour, but with sulphate of iron changes to a dark, or blackish green.

The colouring matter of walnut-rinds has a decided affinity with wool, and being applied to the latter by dyeing, without any mordant, gives it a brownish cinnamon colour, of considerable durability, though it may be rendered brighter and more lasting by an aluminous basis; but on cotton I have not found it produce very lasting colours, even with that or any other basis.

These rinds are most frequently employed to produce, without any basis, particular shades of brown *or dark* colours, upon wool or woollen stuffs, after having been left to macerate in water, and undergo a sort of putrid fermentation during several months. The unfermented rinds, however, with solutions of copper, iron, bismuth, &c. may be made to communicate very lasting chesnut drab, slate, and other dark colours, to wool or cloth.

ART. X.

The Bark of Alder, Betula Alnus,

Possesses a colouring matter which, with the aluminous basis, dyes a permanent and very full, though brownish yellow, or orange, upon wool, cot,

ton, &c. and one which is brighter with the solutions of tin. With the sulphate, or acetate, of iron, it forms a black, and has long been beneficially employed with galls, &c. in forming the black vat for dyeing that colour upon thread and cotton yarn.

ART. XI.

Areca Nuts.

It having been reported that the areca, or Pynang nuts, produced by the areca palm, were employed by the people of Malabar to dye a red colour, I procured and made trial of a parcel of them; but without obtaining any effects which might not be as well procured from many other vegetables, and even from the alder bark, last mentioned. With alum these nuts produced a sort of reddish cinnamon colour, and with iron, a brownish purple black, both of which appeared to be lasting.*

* Some time after my experiments with these nuts had been made, I found, by looking into Loureiro's Natural History of Cochin-china, (original Lisbon edition, p. 567, & seq.) that I had mistaken their proper use. He mentions this species of palm as being extensively cultivated in that country, for the sake of the nuts, and that the fullers make a decoction from them, and apply it to cloths already dyed, to render their colours more bright and lasting. "Fullones telas quascunque imbuere, ut colores diutius servent, et melius expriment." He adds, that they produce this effect by an agglutinating, and not by an astringent, power, ("vi glutinante, non adstringente,") and that for this use many cargoes were sent annually from Cochin-china to China.

ART. XII.

The Ripe Berries of the Privet, (Ligustrum Vulgare)

Being employed as a dye, produced, with the aluminous basis, a light apple green, on wool and cotton, and a bluish black colour upon wool. Canneparius mentions them, (p. 204) as having been anciently employed to make ink, and, indeed, they seem to have been the berries to which Virgil, in one of his Eclogues, applied the name of vaccinium;* but Caneparius appears to have mistaken this shrub for that of the hinna, or lawsonia inermis, which Prosper Alpinus had supposed to be a species of ligustrum.

ART. XIII.

The Myrobalan.

This name has been given in the East Indies to the drupaceous fruit, of two species of terminalia, (viz. Indica, and chebula) as well as to that of the phyllanthus emblica; which last appears to be the myrobalanus of Bontius, and myrobalanus emblica of Loureiro, p. 553. I have already, at p. 351 of my first volume, noticed the terminalia chebula, (which is the terminalia citrina

* "O formose puer, nimium ne crede colori;
Alba ligustra cadunt, vaccinia nigra leguntur."

of Roxburgh, or yellow myrobalan of the shops) and the galls produced on its leaves, as being employed in the East Indies to give a yellow colour on cotton; but I did not include either of these among the adjective yellows of this third part of my work, because, though employed as such in that country, from a paucity of yellow dyes, the colour which they afford partakes so much of a brown tint, as to have but little more right to be deemed a yellow, than that of the alder bark. Their colouring matter is, however, capable of being rendered highly useful in giving a permanent black with an iron basis, especially upon cotton, as will be seen in the chapter allotted to that subject.*

ART. XIV.

Paraguatan Bark.

THE xxiii. vol. of the Annales de Chimie, contains the translation of a report given by Do-

* A ship bound from Cayenne to France, was captured a few years since with a curious collection of the animal and vegetable productions of Guaina, including a dyeing wood, labelled "*Bois de Sassafras de Cayenne*," which last, the agents for the captors sent to me. It was very heavy, close grained, and of a reddish cinnamon colour; and, consequently, unlike the laurus sassafras Upon the aluminous basis it dyed a very high orange colour, (which, however, was not lasting upon cotton) and with iron it gave dark browns.

minique Garcia Fernadez, of some experiments which he had made, by order of the supreme council of commerce in Spain, with the bark of a tree growing in the Spanish part of Guiana, and there called paraguatan, or parugatan; which bark he represented as affording a dye in some respects superior to those of madder and Brasil wood, and as being capable of giving to silk, duly prepared, the various shades of rose and red poppy colour, obtained from safflower; and though this gentleman's report did not manifest much knowledge, either of the principles or practice of dyeing in the reporter, I was induced, by the intervention of a friend, to procure some of this bark from Cadiz; but, after several trials, I found myself unable to obtain from it any thing better than a pale salmon colour, too fugitive to be of any value; I, therefore, notice it here, only that I may obviate disappointment, and, perhaps, loss to those who might confide in, and act upon this report.

ART. XV.

Galls.

THESE are excrescences, produced upon several species of oak, by the cynips quercus, or gall fly, which, by its peculiar structure, is enabled and disposed to deposit its eggs in the young

branches, and other parts of the several species of oak, and thereby occasion a protuberance which increases, until the larva of the insect gnaws through its prison or nidus, and escapes, leaving a perforated cavity therein. The galls, so perforated, are commonly of a light colour, and called white galls. Those in which the larva dies, and which have, therefore, no perforation, are commonly called *blue* galls, being of a darker colour, and affording commonly about one-third more of colouring matter, than an equal weight of the white galls.

Until lately the best galls were brought from Smyrna, Aleppo, and Tripoli; but, at present, a considerable part of those which were formerly exported from the two first of these ports, are carried by another direction from the places where they grow to the East Indies, and are thence shipped to this country. Pliny informs us, (lib. xvi. c. 7.) that the galls most esteemed in his time were those of Comagena, and that the least esteemed were those commonly produced upon the quercus robur.

By long boiling, nearly seven out of eight parts of a given quantity of powdered galls may be dissolved in about ten times its weight in water; after which, Newman found that alcohol would only extract four grains from a residuum of two drachms. The solution, so performed by water, besides matters of less importance, contains colouring

matter, tannin, and a particular acid, (to which the name of gallic acid has been given) all intimately combined; though the first, and most important of these matters, has hitherto been *confounded* with the others. This *colouring* matter precipitates, as I believe, all the metals from their solutions, and the several precipitates, as far as my notes extend, retain nearly the following colours: viz. that of platina, an olive green: that of gold, a greenish brown; mercury, yellow; lead, white or grey; silver, brown; copper, brownish yellow; tin, greyish white; cobalt, pale blue; bismuth, greenish yellow; antimony, bluish white; zinc, a slight greenish brown; nickle, white; columbium, an orange, (according to Dr. Wollaston); osmium, a purple, which changes to a deep blue; and finally, that of iron exhibits a black, which, being diluted, or thinly spread, inclines, more or less, to blue or purple, according to the degree of acidity in the solution whence the precipitation is effected. This *last*, is the most important and remarkable property of galls; and as many opinions, which to me seem erroneous, have been inculcated respecting it, by the highest authorities, and generally adopted, I shall, in a succeeding chapter, endeavour to ascertain the truth in regard to this subject. Here it only remains for me to notice the light cinnamon fawn, or fauve, colour, which galls (like many others of vegetables mentioned in this chapter)

afford, particularly to cotton upon the aluminous basis; and which enables them, as I have found by repeated experiments, to communicate by dyeing a durable nankin colour to calico or to cotton yarn, after the latter has been macerated in milk, then dried, and soaked in a saturated solution of alum, with one-eighth of its weight of lime, afterwards rinced, and dryed, previously to its being dyed in a decoction of this vegetable. A diluted nitrate of lead employed instead of the solution of alum, produces a similar and equally durable colour.

I will observe here, as I shall have no other opportunity of doing it, that some few vegetables, particularly the Peruvian bark, that of the cherry tree, and that of the horse chesnut, (œsculus hippocastaneum) possess the property of producing a greenish olive colour with sulphate of iron; a property which M. Braconnot ascribes to a portion of phosphoric acid, which he found them to contain, conjointly with a yellow colouring matter.—See Ann. de Chimie, tom. 70, p. 290.

Pœrner asserts, that chamomile flowers, with sulphate of copper, will dye wool of a durable green colour, and that fenugree seeds will produce a colour nearly similar, with the same basis.

PART IV.

Of Compound Colours.

In treating of the several colouring matters noticed in the former parts of this work, I have most frequently mentioned the applications of which their *simple* colours are susceptible, in order to form what are justly denominated *compound* colours; because (unlike the former) they may be composed by separate mixtures, of two of the three primitive ones, yellow, red, and blue; yellow and blue forming a green; yellow and red, an orange; and red with blue, a purple, or violet, according to the proportions in which they are mixed; whilst *black*, though in *dyeing upon wool* it may be produced by a very great accumulation and condensation of the blue alone, (as an orange may, by the like accumulation of yellow) is often a compound *of all the three primitive colours.*

But, notwithstanding the mention which I have thus made of the compound colours on different occasions, it seems expedient that I should advert to some of them *more particularly*, before this work is brought to its conclusion.

In dyeing compound colours, the matter which affords one part of the compound, will commonly fix itself upon the stuff to be dyed in parts not occupied by the other component colouring matter; but this sort of arrangement does not hinder the effect intended to be obtained, of an apparently uniform, equal, and homogeneal, compound colour, though it leaves each of these colouring matters without any benefit or support from the other, in regard to its stability or permanency; and it is, therefore, always found, that a fugitive colour is not rendered less fugacious by being employed conjointly with one which is lasting; e.g. a fugitive yellow does not acquire stability by its mixture with an indigo blue; the green resulting from this mixture being found to lose its yellow part in some degree, whilst the blue remains; and this is one of the inconveniencies which attend compound colours; for as they are produced from colouring matters, differing very considerably in their ability to resist the impressions of sun, air, &c. they commonly fade unequally, and thus sometimes produce an unsightly appearance.

CHAP I.

Of Orange, Green, Purple, and Violet Colours, and their various intermediate Shades or Mixtures.

" Cettee partie de la teinture est celle ou les lumieres de l'artiste peuvent etre le plus utiles, pour varier ses procédes, et pour parvenir au but qu'il se propose par la voie la plus simple, la plus courte et la moins dispendieuse."

BERTHOLLET, tom. ii. 302.

ART. I.

Orange, &c.

In several chapters of this work, particularly those which relate to the application of cochineal, quercitron bark, and madder, I have noticed the ways and means by which the various shades of colour, resulting from the mixture or combination of red and yellow, might be produced upon wool and woollen stuffs. It is, indeed, most easy, by combining the cochineal and quercitron bark in different proportions, with the preparation, or mordants employed in dyeing scarlet, to obtain all the possible shades of colour between the rose and the yellow, with their utmost vivacity and beauty, and with sufficient permanency. Some of these, which are but a few degrees or

shades more yellow than the scarlet, may be obtained by employing a portion of either madder, or rubia manjit'h, with cochineal, instead of the quercitron bark; and on the other hand, where nothing higher than the orange is wanted, this may be obtained with great beauty and perfection, merely by an *accumulation* of the quercitron yellow, upon the basis of tin, as mentioned at p. 128, of this volume.

Where shades of orange are wanted, without their utmost vivacity, upon wool and woollen cloths, they may be obtained, by combining the colouring matter of either madder or manjit'h, with that of weld, or of quercitron bark, upon the aluminous basis. In this last case, after preparing the wool or cloth as usual with alum and tartar, it is commonly thought best to apply the red first, and afterwards the yellow, in a separate bath, at least if the red part of the colour is to be applied in a greater proportion than the yellow.

As neither cochineal nor the tin basis can be advantageously employed to dye linen or cotton, it is expedient for these substances to rely solely upon that of alumine, and to select the red colouring matter from those mentioned in chapters three and four, of the preceding, or third part, (especially madder) combining it with the yellow either of weld, quercitron bark, or morus tinc-

toria, in such proportion as will suffice for the colour wanted.

ART. II.

Green.

In the chapter relating to the quercitron bark, I have sufficiently noticed its application for producing, with indigo, all the different shades of green* upon wool, silk, linen, and cotton; and as the blue from indigo is always a component part of this colour, I can have nothing to add here upon this subject, but what relates to the substitution of other *yellow* colouring matters for that of the quercitron bark, particularly those of weld, and dyers' mulberry, called, improperly, old fustic. The latter of these, as I formerly mentioned, has been commonly preferred for dyeing Saxon greens, because its yellow colour is of all others the least depressed by the acid of the sulphate of indigo; but this motive does not apply to those greens, the blue part of which is

* The vegetable productions of the earth, are principally adorned or distinguished by this pleasing colour; and so are many of the animal; particularly birds, fish, reptiles, and insects; and though it has not been allotted by nature to mankind, they have long been accustomed to clothe themselves in it. By the followers of Mahomet, it is, indeed, the most venerated of all colours, as yellow is in China; and the more it partakes of this last colour, by so much is it the more lively and gay.

first communicated by the *indigo vat*, and the yellow by a subsequent dyeing with weld, quercitron bark, dyers' saw-wort, &c. The latter of these is, indeed, in one respect to be preferred for this use, because its yellow naturally inclines to green. When greens are dyed in this way, (i. e from the indigo *vat*,) the blue part of the colour is most permanent, and the yellow first decays, but the reverse happens with Saxon greens. Dyers are frequently required to superadd a brown colour to the *green*, as in that which is called *bottle* green, and this may be well done by employing a little logwood and sulphate of iron, with the yellow and blue colouring matters.

In dyeing silk green from the indigo *vat*, it is commonly thought best to apply the yellow *first*, and to prefer that which the saw-wort affords.

To dye beautiful greens upon cotton, Chaptal recommends that it be first dyed of a sky blue colour, from indigo dissolved by potash and orpiment, then macerated in a strong decoction of sumach, then dried, and soaked in the acetate of alumine, dried again, rinced, and finally dyed with *quercitron bark*; employing twelve pounds of the latter to fifty pounds of cotton. He prefers the quercitron bark to weld for this purpose, because the colour of the latter does not combine so well with sumach, as that of the bark. (See Berthollet, tom. ii. p. 316.)

ART. III.

Purple and Violet.

THESE colours, with all their shades or variations, may be produced *permanently*, and with much vivacity upon wool or woollen stuffs, by combining the rose or crimson of cochineal with the blue of indigo; and they may be obtained with even more vivacity, but less permanency from either logwood or orchall, as mentioned in the first and third parts of this work.

To dye cloth of a purple or violet colour, a light blue, proportioned to the depth of the colour intended to be compounded with it, is first dyed by the indigo vat, and being alumed by the usual boiling with alum and tartar, it is afterwards dyed with cochineal, employing from half to two-thirds of the quantity required for scarlet, according to the shade of purple or violet intended to be produced. Lilac and other light colours of this sort, may be produced by employing these means more sparingly, and by taking advantage of the remnants of colour in the baths employed to dye full violets or purples. Pœrner recommends the sulphate of indigo, instead of the indigo vat, as affording a brighter blue, for producing purple and violet colours; but the blue so obtained will have less stability than the

other, and be liable to fade, in some degree, before that part of the colour which is derived from cochineal.

In making this use of the sulphate of indigo, Pœrner *begins* by preparing the cloth with alum, then dyes it with cochineal, and more than an equal weight of tartar; and afterwards, adds the sulphate of indigo to the same dyeing liquor, and continues the boiling one quarter of an hour longer.

It can hardly be necessary for me to observe, that in each of these ways, the cochineal colour will only be united to the aluminous, and not to the tin basis; and, consequently, that it can only produce a crimson, of much less vivacity than the rose colour which it would afford with a nitro-muriate of tin. But this last mordant has been always avoided in dyeing the purple and violet colours with indigo, because the nitric acid would unavoidably injure the indigo blue. But since my discovery of the utility and facility of employing the murio-sulphate of tin with cochineal, as mentioned at p. 483 of my former volume, this obstacle to the use of a tin basis, for producing purples and violets with indigo, can no longer exist, the muriatic acid having no power to act upon that substance, nor, indeed, the sulphuric, when so much diluted; and my experiments have proved, that the colours in question may be dyed by thus substituting the tin for the aluminous basis,

with an increase of beauty and vivacity, especially if the blue part of these colours be dyed from a sulphate of indigo instead of the blue vat. Some varieties of purple and violet may be produced by substituting madder for cochineal; but though lasting they will be less beautiful. Silk, previously dyed blue in the blue vat, being macerated in the murio-sulphate of tin sufficiently diluted, may be made to receive a fine and lasting purple or violet, according to the shade of blue previously communicated, by dyeing it with cochineal. At present, however, these colours are usually produced upon silk, by first giving it a crimson colour from cochineal upon the aluminous basis, and then passing it through a weak indigo vat, the sulphate of indigo being more fugitive upon silk than upon wool.

Orchella, and also Brasil wood, with the indigo blue, are frequently employed to produce purple and violet colours upon silk, but when so produced, though very lively and beautiful, they have but little stability, except in the indigo part of the colour. Silk impregnated with the aluminous basis, or that from the nitro-muriate, or other solutions, of tin, may be made to receive different shades of purple and violet from logwood, though the colours so produced will not prove lasting.

Cotton macerated in a decoction of galls (employing one pound of the latter to six pounds of

the former,) then dried, and afterwards soaked in a saturated solution of equal parts of alum and sulphate of iron, being dried, rinced, and dyed with its weight of madder, will obtain a *fast* colour, which, by varying the proportions of alum and of sulphate of iron, may be made to incline more or less to the purple or violet; and it may be rendered more bright, by boiling it afterwards for a quarter of an hour, in a weak solution of soap. An acetate or pyrolignite of iron, may be substituted with advantage, for the sulphate of that metal.

Violets and purples still *more durable*, may be given to cotton prepared and dyed as for the *Turkey red;* with this difference, however, that to the alum steep, or mordant, a portion greater or lesser of sulphate of iron is to be added, according as the colour is wanted to partake more or less of the dark or violet shades.

Cotton which has received a light indigo blue, may also be made purple or violet, by impregnating it with the aluminous basis, and dyeing it with madder, as formerly directed.

Besides these results of the several binary combinations of the primitive colours, a much greater variety of tints, (for many of which there are no proper names in the English language,) may be composed, by uniting them *all* in different proportions. Of these Poerner has given numerous illustrations and explanations, to

which I must refer those who desire more information respecting them, especially as it would be impossible for me, by *English* words, to convey accurate ideas of the effects of most of these mixtures; and, moreover, as the dyer in making them, will derive much more advantage from his practice, than from the theory of this art. Many, indeed, of these variations of colour may be cheaply and expeditiously obtained, by *turning* or *saddening* other colours, already described; for which purpose, several of the earthy and metallic solutions, (and especially the sulphate of iron,) with the different acids, alkalies, &c. are commonly employed, and frequently assisted by logwood, galls, sumach, walnut-rinds, &c. by which an almost endless variety of changes may be produced. Some of these have been already noticed in the former parts of this work, and others are known to practical dyers; to whose experience and judgment I must commit this part of my subject, which would otherwise produce an inconvenient extension of my work.

CHAP. II.

Of the Black Dye, and of the common Writing Ink, as connected therewith.

"Nothing more is requisite for producing all the variety of colours, and degrees of refrangibility, than that the rays of light be bodies of different sizes; the least of which may make a violet, the weakest and darkest of the colours, and the most easily diverted, by refracting surfaces from the right course; and the rest, as they are bigger and bigger, may make the stronger and more lucid colours, blue, green, yellow, and red, and be more and more difficultly diverted."

NEWTON, OPTICS. QUERY 29th.

AN object, if any such existed upon or above the surface of the earth, which neither reflected nor transmitted a single ray of light, would be absolutely invisible, and incapable of exciting any sensation or perception of colour. That which is denominated *black*, therefore, does not result from a total absorption, or retention, of the several rays, or a complete obstruction of their motions; but from a very scanty and feeble transmission or reflection, principally of those rays which are dark coloured; consequently, the blackest objects are those which absorb or intercept the greatest proportion of these rays, and especially of those whose colours are most lucid; perfect blackness approaching, or being related most nearly

to the *total absence of all colour*, and yellow being of all colours the most remote from black.

This absorption or interception of the rays of light, so far as it is necessary to produce blackness, may be effected in dyeing and painting, by a great accumulation and condensation of *all* the primitive or simple colouring matters in union with each other;* and even by such an accumulation and condensation of particles, which, while

* It was in this way that those once famous dyers, of the name of *Gobelin*, at Paris, were accustomed, for many years, to dye their finest and best *blacks*. They began by giving to their white cloths a deep blue ground from the *woad* vat, and afterwards boiled them in the usual way, with alum and tartar, and then dyed them with madder and weld, which, upon the aluminous basis, produced a red and yellow in addition to the blue; and from this combination of these three primitive colours, a very durable black resulted, which, having been produced without *iron*, must have been exempted from the rottenness which the oxides of that metal have been generally supposed to occasion. From this combination of colours, no more than a very sparing transmission or reflection of coloured rays could result; as the woad ground would only reflect or transmit those of a blue colour, which last the madder red would either absorb or intercept; and the weld yellow would do the same in regard to the red proceeding from the madder; which red, in conjunction with the woad blue, would permit but a very few rays to escape from the weld yellow. Such an obstruction or retention of the rays of light *generally*, must, of necessity, give the effect or appearance of blackness; an effect similar to that which painters produce by mixing their blue, red, and yellow pigments, in suitable proportions.

dispersed, could only produce a single dark colour, particularly the blue or violet, though a *mixture* and condensation of two colours may render the black more *intense*.* This sort of accumulation or condensation, is produced more easily upon wool than upon linen or cotton, and more easily upon the latter than in a *fluid* mixture.†

There are, however, several animals and vegetables possessing colouring matters, which, by mixture with solutions, or other preparations, of iron, in certain states of oxydation, immediately produce a black liquid, as is seen in the familiar instance of common writing ink; and as the black dye, in most general use, depends chiefly upon a combination similar to that by which ink is produced, it seems proper that we should more particularly consider this latter production, which

* A sufficient proof and illustration of this may be seen at p. 233 of my former volume. But the sulphate of indigo, which, as is there stated, produced a very perfect black on woollen cloth, by mere accumulation or condensation, will not, without additional means, produce a similar colour on linen or cotton.

† A proof of this may be seen, by adding any, even the most oxygenated solutions or oxides of iron, to the infusions or decoctions of madder, when it will be found, that such additions will produce nothing darker than a tobacco or coffee brown. But if linen or cotton be sufficiently impregnated with an acetate or oxide of iron, and dyed with madder, a full and permanent black will be the result, and it is in this way that the most durable black of the calico printers is produced.

happened to engage my attention so early as the year 1770; when opinions demonstrably erroneous respecting it, were promulgated and believed, as they have since been, by the greatest chemists and philosophers of their times.

According to one of these opinions, (then universally admitted, and still subsisting) the property manifested by galls, and many other vegetables, of producing a black ink, or colour, with sulphate of iron, was ascribed solely to another property, denominated astringency, of which the former was assumed to be, both the *measure, criterion, and proof*.* But as this opinion neces-

* Evidence of the prevalence of this opinion at that, as well as at subsequent periods, may be found in books of the highest authority. Dr. Lewis, in his Philosophical Commerce of Arts, a work of great merit, considering the time at which it was published, when treating of the production of ink by galls and sulphate of iron, adds, that "the power by which vegetables produce this blackness, and their *astringency*, or that by which they contract on animal fibre, and by which they contribute to the tanning of leather, seem to depend *on one and the same* principle, and to be *proportioned* to one another." Dr. Cullen also, in the *first* edition of his Materia Medica, (p. 177, 4to.) states as one characteristic of astringents, that their "decoctions thrown into a solution of green vitriol, strike a black colour and form an ink;" and that those "which give the *blackest ink*, provided they are not accompanied with any peculiar acrimony, which discharges their use as astringents, may be reckoned the strongest and best." The celebrated Macquer also, in his Art de la Teinture en Soie, printed in folio, under the sanction of the Royal Academy of Sciences at Paris, says,

sarily produced fallacious conclusions in regard both to the chemical and medical powers, or effects, of a considerable number of vegetables, I thought it my duty to contest it; and this I did, in a communication which was read to the Royal Society, at one of their meetings in the month of May, 1773; in this, among other things, I asserted, that there were a considerable number of vegetable matters, which, though they decidedly manifested *strong astringent powers, were*, as I had found by repeated experiments, *absolutely incapable of producing any degree of blackness*, properly so called, by being mixed with sulphate of iron; and, on the other hand, that there were *other vegetables in which no astringent power was discoverable*, though they *copiously produced a black colour*, when mixed with this sulphate.

I alleged various instances of each of these *sorts* of vegetables in support of my assertion,*

" Engeneral toute teinture noire est composée pour le fond, des ingredients avec lesquels on fait l'encre a écrire ; c'est tousjours du fer dissont par des acides, & precipité par des matieres astringentes vegetales." Much more evidence to this effect might be adduced ; if the fact intended to be established by it were not so notorious, as to render it unnecessary.

* It will, probably, be thought sufficient for me here to mention the following as instances of these several sorts of vegetables, viz.

Among those which are most decidedly astringent or *acerb*, but incapable of producing blackness with iron, are

1st. The bark of the quercus nigra, Lin. or quercitron bark,

and, as I believe, sufficiently demonstrated, that, though the so called astringent vegetables, do

lately described : its taste is strongly astringent; it efficaciously coagulates and precipitates glue, and is generally employed in North America to tan skins, which it does speedily and effectually, though its decoction or infusion will not produce any thing more than an olive brown or drab colour with iron, in any state of solution or oxidation; nor is it capable of dyeing a black colour with that basis, by the greatest possible accumulation or condensation even upon wool; as I know by the results of many trials.

2d. The bark of the rhizophora mangle, or red mangrove, also lately mentioned, which manifests great astringency to the taste, precipitates glue expeditiously and copiously, and tans skins very speedily and efficaciously, being generally preferred and employed for that purpose by the Spaniards in different parts of America; but, like the quercitron bark, it is utterly incapable of producing a black ink, or dyeing a black colour, with any solution or preparation of iron, even though accumulated and condensed upon wool, by long boiling therewith.—Mahogany bark possesses astringent and other properties exactly similar to those of the mangrove bark, and, like the latter, it is incapable of producing a black with iron.

3d. The extract of the mimosa catechu, formerly called terra japonica, and by Linnæus erroneously supposed to have been obtained from that species of palm which produces the areca nuts, and which he, therefore, denominated areca catechu. There are two varieties of it, one imported chiefly from Bombay, and the other from Bengal; but, though differing in external appearance, they manifest the same properties. Both of them are highly astringent, though a little sweetish to the taste; and both have been found by Sir H. Davy and Mr. Purkis, of Brentford, to tan skins most powerfully; but neither is capable of producing a black ink, or dyeing a black colour,

many of them possess matters capable of producing blackness with iron, (in a suitable state of

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with any, even the *most oxygenated* preparation of iron. This I assert, from the results of experiments repeated many times, not only with parcels of this drug as sold in the shops, but with some choice specimens which I received from Dr. Roxburgh, the late Mr. Tiberius Cavallo, and others; of which no one, in a single instance, was found to produce any thing darker than a *snuff* colour, with the most oxidated sulphate of iron, even that to which nitric acid had been purposely added, to increase, (as it does with galls) the blackness resulting from its application. I have *asserted* these facts more *distinctly*, and in *stronger terms* than I should have thought necessary, had not Sir H. Davy, in the very lucid and judicious account which he gave to the Royal Society, of his experiments and observations on the constituent parts of astringent vegetables (published in the Philosophical Transactions for the year 1803), after admitting that "the *least* oxygenated sulphate of iron produced no change in the infusion" of catechu, stated (at p. 255) that "with the *most* oxygenated sulphate, it gave a *dense black* precipitate, which, when diffused upon paper, appeared *rather more* inclined to olive than the precipitate from galls:" and had he not also stated (at p. 258) that an aqueous solution of the pure extractive matter of catechu being added to the solution of oxygenated sulphate of iron, it communicated a fine grass green tint; and that a green precipitate was deposited which became *black* by exposure to the air." Before these statements fell under my observation, I had made, probably, fifty experiments with mixtures of *catechu* and iron in different states of oxygenation, which were begun in the hope that the former, from its moderate price, might be found capable of being advantageously employed upon a large scale, in producing a *prosubstantive black* for calico printers; but I had completely laid it aside, with the fullest conviction, that it could not be made to produce any thing *like*, or even *approaching to a black* colour, by or

oxidation) they do not possess it exclusively, but in common with other vegetables which are

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with any preparation of iron whatever. In consequence, however, of these statements by Sir H. Davy, I was induced to renew my experiments, and with a greater variety of specimens of the catechu; but from none of them could I produce, by any degree of oxidation given to the iron, or any subsequent exposure of the mixture to the air, any thing darker, when diffused on paper, than the snuff colour already mentioned, which, to my apprehension, is very far removed from black. Whether the catechu employed by him was adulterated, or whether, from believing that according to the general opinion, this substance as an astringent *must produce blackness with iron,* he was led to employ expressions *exceeding the effect* really produced, I know not—but there seems to have been a want of Sir H. Davy's *usual accuracy* in these statements, particularly when he describes the *dense black* precipitate from catechu as appearing, by diffusion upon paper, "*rather more inclined to olive than the precipitate from galls.*"—Probably no person ever made more precipitates than I have done from mixtures of iron and infusions of galls; and I do not recollect that any one of them *ever inclined to olive,* though, by varying their proportions, a variety of shades or tints may be produced between a reddish brown black, and a bluish or violet black—the former occurring when the galls are in excess, and the latter, with an excess of iron or its oxide. But how *an olive* could result from any such mixtures I know not.

Of the vegetables which *manifest no astringency,* though they abound in colouring matter, which produces a black ink, and black precipitates with iron, the following instances may suffice, viz.

1st. The bark of juglans oblonga alba, white walnut or butter nut of North America, of which the decoction very decidedly and copiously affords a black ink with sulphate of iron, and

destitute of astringency; and that this last property, therefore, is not necessarily or constantly connected with, or denoted by that of producing a black colour with iron, or any of its preparations.

strongly communicates that colour, by dyeing, to wool, silk, linen, and cotton, though it discovers no astringency to the taste, nor causes any precipitation with gelatine.

2d. Logwood, or its decoction, which is sweetish, but not in any degree acerb to the taste, nor capable of producing the slightest precipitation with glue, (until by long keeping, it has acquired new properties, as stated at p. 341 of this volume) and yet its abundant power of producing a black ink, and of dyeing that colour with iron, has long been notorious. The fact, indeed, of its possessing this power has induced physicians to suppose, that it *must* be an astringent, and to employ it as such medicinally—which is one proof of the errors resulting from the groundless opinion here controverted.

3d. Brazil wood, and the several other species cæsalpinia, lately mentioned, the decoctions of which are completely destitute of any thing like an astringent, austere, or rough taste, and of even the slightest power of occasioning a precipitation with gelatine; and yet, like logwood, they copiously afford a very black ink with iron, and dye that colour with sulphate of that metal.

Other and similar instances might be found in madder, galium, &c. which notoriously afford most permanent blacks, even upon linen and cotton, with iron, though they are completely destitute of astringency and of the tanning principle. The like instances may also be found in the animal kingdom, particularly in the cochineal insect, which, with sulphate of iron, produces a deep black ink, and a black dye, though it has never been found to possess the least astringency.

At that period, the rottenness which was generally complained of as attending black cloths, had been ascribed to the *acid* part of the sulphate of iron, employed to dye that colour,* and this acid, being also supposed to accelerate the decay of writing ink, I was induced to endeavour to effect a direct combination of iron with the soluble part of galls, without the intervention of any acid; and for this purpose, having made a decoction of galls, I put to it a quantity of clean iron filings, and, in a little time, perceived that this mixture occasioned the production of a considerable number of air bubbles, and an escape both of inflammable air and carbonic acid gas, together with a brownish discolouration upon its surface; which discolouration continued to increase, as well as the extrication of hydrogen and carbonic acid gases, for the space of twenty-four hours; when the mixture had acquired a decidedly full black colour on its surface, though internally it

* That I may not multiply proofs of this well-known fact unnecessarily, I shall content myself with the following extract from M. Macquer's Art de La Teinture en Soie.—viz :

"Ce qu'il y a deplus essentiel a observer sur la teinture noire, c'est qu'on général, elle altere et énerve beaucoup les ètoffes ; ensorte que celles qui sont teintes en noir, sont tousjours beaucoup plustôt usèes, toutes choses égales d'aillieurs, que celles que sont teintes en d'autres couleurs: C'estprincipalment a *l'acide vitriolique* de la caperosè, lequel n'est que imparfaitment saturè par Le Fer, qu'on doit attribuer cet inconvénient." Other and similar proofs will occur speedily.

appeared, upon examination, to be only of a brownish purple; but, being applied to paper by a pen, it soon became black, by an absorption of oxygene. This was in the summer season, and the decoction of galls having been left to act upon the iron filings twenty-four hours longer, I judged, from its appearance, that a sufficient solution and combination of iron had taken place, and, therefore, separated the fluid part, by a strainer, from the iron filings; and by exposing the former in an open vessel, I found the next day, that it was become deeply black, and that (being applied to paper with a pen) it was capable of answering the purpose of ink extremely well. Having repeated this experiment several times with the same result, I employed this direct combination of the colouring matter of galls with iron, as a *dye* to wool, silk, and cotton, and found it to produce a good black upon each of these substances; and I, therefore, thought myself warranted to conclude, in opposition to what had been alleged, particularly by the late Dr. Percival, (in his Essays Medical and Experimental, and especially from his Experiments 37—39) that the sulphuric acid was not *an essential* constituent part of ink, or of the black dye, but that both might be produced, and, as I thought, with advantage, by directly combining the soluble part of galls with iron. And these conclusions, together with the experiments from which they had

been drawn, were likewise stated in the communication which I made to the Royal Society, as lately mentioned; but as I then announced my expectation of speedily *adding* to it a farther account of the benefits to be derived from the application of this *discovery*,* to the purposes of dyeing, the Committee of Papers thought proper to wait for that *addition*, before they decided upon the publication of my first communication; and having waited in vain, until the 3rd of March, 1774, the late Mr. Walsh, then a member of the council, on that day wrote me a letter (which is now before me) requesting in their behalf, to know my "intentions about giv-

* Dr. Lewis, though he had completely adopted the opinion which I recently mentioned, of the real or supposed injurious effects of sulphuric acid, as a constitutional part of ink, and of the black dye, and though he made trials of iron dissolved by other acids, instead of the sulphate of that metal, without any benefit, as he conceived, yet he did not attempt to effect a combination of iron directly with a decoction of galls. Such an attempt was, however, made afterwards by the late Dr. Percival, but as he employed a *cold* infusion of galls, and, probably, in *cold weather*, without allowing sufficient time to obtain the desired effect, his experiment failed, and he concluded this *direct* combination must be impracticable. It was, however, effected by M. de Morreau, and his associates of the Academy at Dijon, about the year 1778, *five years* subsequently to my communication to the Royal Society on this subject; of which, however, it may be presumed, that these academicians were ignorant.

ing an additional paper to the society on the subject of colours, the Committee of Papers having deferred the consideration of that of the last year in the expectation of such a paper." In answer to this letter, I informed Mr. Walsh that it was still my intention soon to finish, and send to the Society the additional paper in question, and also intimating, that as the Committee had waited so long for it, my desire was that they should continue to do so. After this, circumstances occurred, of which a detail would now be useless, to hinder me from fulfilling the intention so declared; and this additional communication having never been made, no notice was, of course, taken of the *first*, in the Philosophical Transactions; and, consequently, the errors which it was intended to correct were left to subsist, as some of them do, at this time.

The ink, formed by this direct mixture of iron-filings with the soluble parts of galls, when they were combined in suitable proportions, was found, if employed within a few weeks after being made, to produce upon the paper a very smooth, full, and lasting black; but when long kept, it did not fulfil my expectations, as it seemed even more disposed than common ink to become mouldy, and also to concrete and subside in the form of a black powder; defects which, in common ink, probably are, in some degree, obviated by the influence of sulphuric acid; for though this acid

may, as is supposed, accelerate the decay of ink after its application to paper or parchment, as, in old writings, it probably retards the commencement and progress of mouldiness, whilst the ink is in a *liquid* state, and enables the water for a longer time to hold in a state of solution or suspension, the black compound of oxydated iron and the colouring matter of galls, which, if their affinities are not counteracted by sulphuric, or some other acid, will unite more *closely* and exclusively, and by detaching themselves from their aqueous solvent, will subside like *charcoal* finely powdered; an inconvenience, indeed, to which common ink is, in some degree, liable, and more especially when it is either much diluted, or not sufficiently gummed.

When the decoction of galls, and the iron filings, were mixed and left together, until an *excessive proportion of the latter* had been dissolved and combined with the former, the black compound appeared still more disposed to concrete exclusively, and subside in large particles; and if, by shaking, these were again diffused through the water, whence they had subsided, and applied by a pen to the surface of paper or parchment, they did not, in the smallest degree, penetrate the substance of it, like common ink, but, when dry, might be rubbed off, as if powdered charcoal only had been applied. They were, indeed, easily made soluble in water, by

adding to it a sufficient portion of sulphuric acid; but this only produced a mixture similar to the common ink, when made with an excess of the sulphate of iron. And, after many trials, I found that the best expedient for rendering ink useful, when produced by a direct mixture of iron-filings with a decoction of galls, was that of combining the latter with only so much of the iron as was barely sufficient to produce a black colour, when the mixture had become sufficiently oxygenated. By this sparing use of the iron, and the addition of a suitable proportion of gum, the deposition of black matter was, in a great degree, obviated, and the ink, from specimens which I have preserved of it, has appeared to be very lasting, at least if employed before it had suffered by long keeping in a moist state, in which it was still liable to become mouldy, perhaps more speedily than ink made with the sulphate of iron. Delaval has, however, greatly commended ink formed by this direct mixture of iron-filings and the decoction of galls, (though without acknowledging the inventor); and Proust, as Berthollet observes, (tom. i. p. 126,) has given a decided preference to such ink.

Some years after my communication to the Royal Society, Scheele, by exposing a cold infusion of galls to the open air during a whole summer, obtained from the residuum, which had become almost dry, (by dissolving it with hot water,

filtering, and again evaporating) a crystallized salt, which, when added to a solution of the sulphate of iron, made it black like a decoction of galls. This salt, which has since been denominated *gallic acid*, Scheele supposed to *exist ready formed* in the galls, but to be so intimately combined with some mucilaginous or other matter, as to be incapable of crystallization, by the ordinary means, or without some internal movement or change, like that which occurs during fermentation: and this supposition has been since generally adopted by chemists, who have attached great importance to Scheele's discovery of the so called gallic acid, and attributed to it all those properties, which have been thought to characterize and distinguish that class of vegetables, commonly called astringents; though they have, as I think, done it most unwarrantably, because Berthollet and others have all failed in their numerous attempts to obtain this acid from even a single one of this class of vegetables;* and not being found or contained in them, we cannot be justified in taking *it* as the

* See his Elements, &c. tom. i. p. 108, &c. Davy (see Philosoph. Transactions for 1803, p. 268) was disappointed in his expectation and endeavour to obtain gallic acid from the fruit of the *terminalia* chebula, or yellow myrobalans, which, by my experiments, have appeared to afford, when the nut was removed, nearly as much of that colouring matter which produces a black with iron, as the best Aleppo galls, and to produce this colour as efficaciously, perfectly, and permanently, even upon linen and cotton, with the several preparations of iron.

exemplar and evidence of their properties. There is, indeed, so far as I can judge, good reason to believe, that this gallic acid has no natural existence any where, and that it is a production of art, or, perhaps, more strictly a modification of the acetic, or other acid, to which astringents are principally indebted for their *acerbity*. That an important modification of this acid should take place, during the *long* continuance of Scheele's process, might well be expected, especially as he has himself stated considerable changes to have occurred in regard to the infusion of galls from which it was obtained, and which had not only become very mouldy, but was covered by a mucous pellicle, and had *lost all its styptic taste*, a considerable time before the operation terminated,

When, in addition to Scheele's discovery, Seguin had taught us how to recognize or ascertain the tanning principle in vegetables, by mixing glue with their infusions, or decoctions, attempts were made to separate the latter from the gallic acid, and obtain each in a distinct and pure form.

Among the means employed to effect this separation, those recommended by Proust, and which depend chiefly upon the muriate, or nitro-muriate of tin, (see Ann. de Chimie, tom. 25 and 41.) seem to be most efficacious, though they are admitted to be insufficient; the gallic acid, after such separation, always retaining a little of the tanning principle, and the latter a little of the acid.

I have given some account, in the preceding chapter, of the origin and constituent parts of galls, to which I must refer my readers. From the *cause* and manner of their production, we might naturally expect that they would only consist of matters, afforded by the juices of the oak on which they grow; which juices, in consequence of the stimulus given by the larva of the gall-fly to the adjacent vegetable fibres, circulate and accumulate more copiously than they would otherwise do, around the offending insect, by a sort of *inflammatory process*, like that which is produced by a thorn in human flesh; and, therefore, though these vegetable excrescences might contain some matters derived from the oak, in a more *distinct* and *pure* state than that in which they are naturally produced by the tree itself, they could contain *no* matter which the tree had not produced, unless it were afforded by the *insect*. But the latter is not known, so far as I can discover, to possess any matter capable of producing a black with iron, and even if it did, we might reasonably conclude, that it must have been imbibed or derived from the juices of the oak, which notoriously contain it; and, therefore, though galls confessedly contain both tanning and tingent matters, in a more *concentrated* and *pure* state than that in which the oak affords them naturally, it may be presumed, that in *every other respect* they are the *same identical*

matters; even though it should be true, as M. Chaptal supposes, that galls possess something of an *animal* nature, (which, indeed, they must do, if employed before the insect has escaped from them). For unless it were proved, that the insect possessed, and could impart to the galls some tingent matter *peculiar to itself*, and similar to the supposed gallic acid, there is no reason to suppose that the *animal* nature of the gall fly, or its larva, would materially change the properties of either the tanning or colouring matters *naturally* produced by the oak; and we are warranted in believing, that in fact no such change is produced by this insect, because M. Berthollet states that, by his experiments, the *white* galls (from which the larvæ must have escaped) appeared to yield more of the gallic acid than the *blue* galls, which always retain the insect. (See Elements, &c. tom. i. p. 108, &c.). And as he also states, that he had not been able to detect any gallic acid in oak bark, we have an additional reason for believing, that this acid is not a natural production; more especially as, since different ways of procuring it have been made known,* its properties, as Bouillhon La Grange has remarked, are found to differ according to the method in which it has been obtained.

* One of these additional ways, not yet mentioned, is that discovered by Deyeux, of distilling the precipitate of an infusion of galls, made with carbonate of potash, by which a *very small* proportion of this acid may be obtained.

(See Ann. de Chimie, tom. lx. p. 156). Many new names and distinctions among the acids have, indeed, been introduced within the last forty years, founded only upon *trivial* modifications, *produced by art*; and if my memory does not mislead me, Scheele also obtained the supposed acid of sugar, as well as gallic acid, from galls.

It will have been observed, that in the preceding parts of this work, I have invariably applied the name of *colouring* matter to those parts of vegetable dyeing drugs which are found to produce colour with an earthy or a metallic basis; and I have, certainly, never been able to discover any good reason for doing otherwise, in regard to those vegetable matters which afford ink, or a black dye, with iron; matters which, indeed, are extremely various in their *other* properties, and *even in the sorts of black* which they produce; though chemists have, as I think improperly, confounded most of them, under the general denomination of *astringents*; a term which may be unobjectionable, as signifying *acerbity* in vegetables, but not as indicating, or being invariably connected with, any such property or matter as they have been supposed universally to possess, that of producing a black colour with iron.

The tanning *principle*, if it deserves to be called a *principle*, notwithstanding its varieties, is found much more constantly in the acerb or astringent vegetables, than the colouring matters producing

black with iron; and this last is very frequently united with tannin, but not invariably, as we have lately seen by the facts stated in regard to the catechu, and other matters employed for tanning.

M. Berthollet has appropriated an entire chapter to the subject of *astringents*, (des astringents) which name, says he, designates a property *common* to a great number of vegetables, ("une proprieté commune a un grand nombre de vegetaux"): he confesses, indeed, that there is no other property in them, concerning which people have been satisfied with such vague ideas; nevertheless, continues he, *every substance which renders a solution of iron black*, has been commonly deemed astringent, or acerb;* and this effect has been attributed to *one identical principle*, residing in the substances produ-

* Sir H. Davy (probably from what he saw in his experiments with *catechu*) seems to have endeavoured to *amend* the common definition, or notion of the properties of an *astringent*, or rather of the *gallic* acid. "The presence of tannin," says he, "in an infusion, is denoted by the precipitate it forms with the solution of glue or of isinglass: and when this principle is wholly separated, if the remaining liquor gives *a dark* colour, with the oxygenated salts of iron, and an immediate precipitate with the solutions of alum and of muriate of tin, it is believed to contain *gallic acid* and extractive matter." Phil. Trans. for 1803, p. 234. By this substitution of a *dark*, for a *black* colour, as a criterion of the presence of *gallic* acid in an infusion, to which an oxygenated salt of iron has

cing this effect;* experience, however, says he, has since shewn that it is necessary to admit *two sorts of astringents*, viz. tannin and the gallic acid: and he adds, that both of these precipitate iron, and produce with it a bluish black colour: (tom. i. p. 105) but this, though true of the tannin afforded by most of the oaks, is not true of that contained in the quercitron *oak*, or in the mangrove, &c. nor of that which chiefly constitutes the *catechu*, as I have already noticed, so that we find, even in this, the most recent and correct elementary work on this subject, a *renewed assertion* of the errors, which I long since controverted, and which I am now endeavouring to overcome, by facts, which, when properly made known, cannot

been added, a foundation is laid for very erroneous conclusions; there being, so far as my recollection extends, no *adjective* colouring matter, either animal or vegetable, which is not *darkened*, at least, by the oxygenated salts of iron; and if the latter do not darken some of the *substantive* colouring matters, as that of indigo, and that of the buccinum lapillus, it is only because these matters form no combination with the oxide of iron.

"* Cependant on a regardé ordinairement comme astringent, ou comme acerbe, toute substance qui change en noir une dissolution de fer; on a supposé que cet effet étoit dû à une principe identique, qui réside dans toutes les substances qui le produisent. L'experience à fait voir ensuite qu'il falloit admettre deux espèces d'astringent, savoir, le tannin, et l'acide gallique." Elements, &c. tom. i. p. 95, 96.

fail of producing more accurate opinions respecting these matters.

M. Berthollet, after having thus arranged the tanning principle, and the gallic acid, as *two sorts* of astringents, proceeds (tom. ii. p. 113, &c.) to notice and compare their respective properties; and in doing this, he represents the affinities of tannin, as differing but very little from those of the gallic acid, at least in those combinations which relate to dyeing; but he remarks, that the compounds of the latter, generally manifest more stability, than those of the gallic acid; that it forms an insoluble substance with gelatine, whilst the gallic acid combines, and remains with the latter in a fluid state; and that it unites with the solutions of iron, forming a precipitate, which speedily separates and subsides; whilst the gallic acid merely produces, with these solutions, a transparent (black) liquor, from which the coloured particles only subside, *after a great length of time*, and by the aid of particular circumstances: but the most important difference between these matters, presented itself in applying them to silk, linen, and cotton; which, after being impregnated with the gallic acid, could not be made to take a black colour, by being dyed with any solution of iron; though these substances, when treated in the same manner with tannin, obtained good blacks. Similar results happened when the iron basis was *first* applied to the silk, &c. and

the tannin and gallic acid *afterwards*, and from these experiments he infers, that though the gallic acid may *co-operate* with tannin, in producing a black by dyeing, it must be useless for that purpose when employed *alone* (with iron). He admits, however, that the tanning principle acts efficaciously in this way *without* the gallic acid.

After this account of the most generally received opinions, respecting the gallic acid and the tanning principle, I will venture here to state my own conceptions of these matters. I have lately intimated my inability to discover any good reason for not considering the tingent part of galls, oak bark, and other vegetables, producing a black with iron, *merely as a colouring matter*, at least in regard to this effect, as I have done in regard to the substances which afford other colours; and, indeed, it has long appeared extraordinary to me, that this property in *oak galls* should have almost exclusively engaged the attention of chemists and philosophers, whilst other vegetables, particularly the bark of the acer rubrum, and the fruit as well as *galls* of the chebula terminalia, produce a *similar* effect, with equal efficacy, and perfection. These vegetables, like the oak and its galls, give proofs of a considerable portion of *acidity*, (on which their acerbity chiefly depends,) and also of that which is called the tanning principle; and both of these are so intimately combined, with what I shall continue to denominate

the colouring matter, that no means have yet been discovered by which either of the former can be obtained separately and distinctly from the latter; and, therefore, it has been found invariably, that the so called gallic acid, and the tannin procured from galls, were either of them always capable of producing a black ink with solutions of iron. But chemists, prepossessed by certain notions about acidity, have strangely overlooked this colouring matter, and ascribed its effects to the supposed gallic acid, as they have done in regard to the colouring matter of Prussian blue, calling it *Prussic acid*, with even greater impropriety, because the latter does not manifest the smallest acidity, whilst vegetables remarkable for their acerbity, do unequivocally give proofs of it; but so far as I can discover, this, their acidity, though co-existent and united with their colouring matter, is distinct from it, and *useless* in regard to its tingent effects.

In Scheele's process for procuring the supposed gallic acid, the tanning and colouring matters seem to suffer a partial decomposition, though some of both, and especially of the latter, (and, perhaps, the finer and purer parts of it) remain dissolved by, and united with, the acid producing the ascerbity of the galls, which acid preserves them from the decomposition or destruction that occurs to the other parts; and in this way the colouring matter, so united and preserved,

is combined with a much greater proportion of vegetable acid, than it is in its original and natural state; and this increased proportion of acid renders it, when mixed with the sulphate of iron in the form of an ink, less disposed to separate and subside, than it is in common ink; for the same reason as that which I lately mentioned, to explain why common ink, made with a solution of iron by sulphuric acid, was more exempt from this defect, than ink produced by a direct mixture of iron-filings with a decoction of galls.

I have here supposed *three* principal constituent matters in galls, and the other vegetables under consideration, though it is very possible that the matter producing colour, and that possessing the property of tanning skins, may be *one* and the same, instead of being *two*, inseparably combined.

On this point it must be extremely difficult, if not impossible, to acquire certainty. But if *one identical matter* produces these several effects of tanning, and affording colours, this matter must be susceptible of various modifications, and actually possessed of properties, which differ even in the quercitron oak, the red mangrove, the mahogany, the mimosa catechu, &c. and which are *very* dissimilar in their tingent effects, at least from those of the tanning and colouring *matter*, as it exists in the common, as well as most

other oaks, and in the acer rubrum, the terminalia chebula, and many other vegetables.

M. Berthollet supposes, that the several vegetables which produce the black colour with iron, must *all* have *one* common mode of acting upon that metal; and after noticing the fact, stated by M. Monnet and his associates, (the Dijon Academicians,) that, by adding a decoction of galls to solutions of gold and silver, these metals were not only precipitated, but *revived* by it, he assumes this *common mode of action*, to be that of producing an abstraction or separation of oxygene from the metallic oxides, and especially that of iron, and thereby occasioning such a partial reduction of the latter metal, as will bring it to the state of a *black oxide*, or Æthiops;* and he also assumes, that these vegetable astringent, or colouring matters, by combining with the oxygene so abstracted, undergo a sort of *combustion*, slight, indeed, but sufficient to render the *carbone* of the vegetable astringent, or colouring matter, *predominant* ("de maniere que *le charbon devient predominant.*" See tom. i. p. 122). And by this supposed reduction of iron, to its naturally blackish colour, and the conversion of the

* This notion seems to have originated with M. Fourcroy, who (as M. Berthollet observes) had, in 1785, supposed the gallic acid to colour iron black, by restoring it *almost to its metallic state.*

vegetable matter to a sort of charcoal, he supposes himself to have given a satisfactory explanation of the production of blackness in common ink, &c.

In regard to the carbonization of the vegetable part of ink, &c. I shall state my opinion presently; and in regard to the reduction of its ferruginous part to the state of a black oxide, I must here mention the fact which has been strongly insisted upon by Proust, and observed by all who have attended to the subject, I mean that of the superior efficiency of the *most oxygenated* oxides of iron in producing the *blackest ink*; and the *total inefficiency* of that metal, to produce a black colour with galls when it is but little oxidated, as in the *green* sulphate of iron; at least until the want of oxygene is supplied by an absorption of it, from the atmosphere. This fact is, indeed, admitted by M. Berthollet, but in opposition to it, he alleges, (tom. i. p. 105, 6,) that this unfitness of the *green* sulphate of iron, or of a muriate (but little oxidated) of that metal, to produce blackness with galls, depends solely upon the *too strong action* which these acids exert, upon the iron thus sparingly oxygenated;*

* The following facts seem incompatible with this explanation, viz.

Having dissolved iron by pure muriatic acid, with an apparatus which, whilst it permitted the escape of hydrogene gas,

which action, as he supposes in another place, (Essais de Statique, Chim. tom. ii.) disables the vegetable colouring matter, (or gallic acid, as he terms it,) from attracting or taking from these acids, enough of the iron to produce the black colour; and he supposes, that a confirmation of this explanation may be derived, from the effects which are produced by the *direct mixture* of iron-filings with a decoction of galls, by which a black

precluded the access of oxygene from the atmosphere, I obtained a *white* muriate, or *oxide* of iron, which I mixed with a decoction of galls recently made, and found, as I expected, that the iron in this state did not, in the slightest degree, change the colour which the decoction of galls had previously exhibited. Without loss of time, I immersed three bits of calico in this mixture, and when they had imbibed as much of it as they were capable of doing, I held one of them, which (like the others) was of a pale nankin colour, over the fumes of nitric acid, by which it was sensibly blackened in a single minute. Another piece I dipt in aqua fortis, and found it to be instantaneously blackened thereby. The third bit was spread out, and left to dry in the open air, by which, after twenty-four hours, the *edges only* were become black by an absorption of oxygene.

As in this experiment an instantaneous blackness was produced by dipping one of the before-mentioned bits of calico into nitric acid, and a very speedy blackness by the application of its fumes to another, no one can pretend that the previous pale nankin colour, or the non-appearance of a black, was occasioned by an *excess of acid;* since with an addition, and a very great one, of acid, the *blackness was suddenly produced:* and this production can, I think, be ascribed to nothing but the oxygene which nitric acid relinquishes more readily than the sulphuric, which acid did not produce a similar change of colour.

colour is produced, though the iron, by this mixture, can, as he says, be only brought to the *lowest degree* of oxygenation, ("le fer ne peut etre amené qu'au degré le plus bas d'oxidation." See Elements, &c. tom. i. p. 105.) That the iron is but *little oxidized*, for some time after, being put in contact with the decoction of galls, I readily admit; but so long as it continues to be but sparingly oxidated, so long the mixture will only exhibit a *reddish brown colour;* but this will gradually become darker, in proportion to the acquisition of oxygene, by absorption from the atmosphere, and probably also, by some decomposition of the water, affording the hydrogene gas, which continually escapes:* a principal part.

* The acid which predominates in galls and other astringent vegetables, appears to act upon iron like the sulphuric and muriatic acids; though more slowly; and like them, to favour a decomposition of water, which M. Berthollet supposes to happen when iron is dissolved by a direct mixture with the decoction of galls; and this supposition enables us to account most readily for the production of hydrogene gas, which is extricated in consequence of such mixture. The affinity, however, between iron and the colouring matter of galls, seems also to co-operate in dissolving the metal. For having boiled powdered galls in water with a portion of carbonate of potash, which was more than sufficient to neutralize their acid part, and having added iron-filings to this decoction, I found, that though there was but very little appearance of a solution or combination of the metal with the colouring matter of the galls, during the first twenty-four hours, a solution did ultimately

however, of the oxygene producing this change, must be derived from the atmosphere, because the colour of the mixture is always many degrees darker at the surface, than it is a few lines below it, and least dark at the bottom. It will, indeed, after some time, if not stirred, appear, in a transparent glass cup, to be *quite black* at the top, and to recede in other parts gradually from this colour, in proportion to their distance from the surface. By frequently stirring the mixture, and allowing time for the decoction or infusion of galls to acquire a sufficient portion both of iron and of oxygene, a very full and perfect black will be produced; but we have no reason, so far as I can judge, to believe, that the *component parts* of this colour are not *then* as much oxygenated as those of a similar colour, produced by adding iron, at the *maximum of oxidation*, to a decoction of galls. That iron highly oxygenated, is necessary to produce a full black colour *immediately*, or without waiting for an absorption of oxygene from the atmosphere, is *now* well known: though it seems difficult to understand why it should be so, upon M. Berthollet's supposition, that the iron which contributes to that colour, is only in the state of a *black* oxide For though galls, and

take place, so far as that, at the end of six days, in the summer season, an ink sufficiently black was produced, which also gave a black colour to cotton dyed with it.

other similar colouring matters, be admitted to have a power of abstracting oxygene from iron, it cannot be necessary that *an excess* of oxygene should be combined with that metal, *merely that the galls, &c. should have an opportunity of exerting this power, by taking it away.*

It is, indeed, true upon M. Berthollet's assumption, that this superfluous portion of oxygene may be requisite to produce the *combustion* which galls are supposed to undergo, in order that their carbon may be rendered *predominant;* and this consideration makes it expedient that I should here propose some observations in addition to the facts stated between pages 54 and 62 of my first volume, and in opposition to the supposed carbonization of colouring matters by such means; especially as M. Chaptal has adopted the same theory, in his Chim. appliqueé aux arts, (tom. iv. p. 282 and 283,) where, after stating that the decoctions of astringent vegetables bring iron into the state of an Ethiops, he adds, that by the action of oxygene upon these decoctions, their carbone is made *visible* or *naked*, ("le carbone *est mis a nu.*") And he adds, that in order to understand this last phenomenon, it should be known, that *next after indigo*, gall nuts are, of all vegetable substances, that which furnishes the *greatest proportion of carbone;* so that, when oxygene is applied to a decoction of these nuts, it forms water with their hydrogene, and their car-

bone is set *almost free.* ("Le carbone devient presque libre.") Against the existence of carbone as such *naturally*, and with a *black colour*, in vegetable matters of any sort, and, consequently, against the supposition of its being in this way made *naked* or set free, I have alleged facts and arguments (at p. 65 and sequ. of my former volume,) more than sufficient, as I believe, to refute this part of M. Berthollet's theory; and I cannot help thinking, notwithstanding my great deference for every thing sanctioned by such high authority, that M. Chaptal's allusion to indigo, as an elucidation of this supposed phenomenon, was at least inconsiderate: for if the colour of indigo depended upon any thing like carbone, or its basis, that combination with oxygene which is indispensably necessary to render it *blue*, would, upon M. Berthollet's assumption, make it *black* like charcoal; and the putting indigo into *four times its weight* of the most concentrated oil of vitriol, or sulphuric acid, (as is commonly practised for the Saxon blue,) would not, as it is known to do, render its blue colour much more lively and bright, but would, on the contrary, convert the whole to a black coal; as this acid invariably does with vegetable matters containing the basis of carbone or lignin. Not, however, by its oxygene, so much as by the sulphur with which that oxygene is combined; for the nitric acid, which gives up its oxygene more easily, and in greater

purity than the sulphuric, does not blacken any vegetable matter, so far, at least, as my observations have extended; but, on the contrary, renders them all white; and this fact alone seems decisive in its operation against the theory in question; for if it were true, the sulphate of iron ought to be preferable to the *nitrate*, though the latter, as I have often experienced, is by much the most efficacious in producing a very deep black ink, with a decoction of galls; and the oxygene which this nitrate could alone impart, to the supposed carbonaceous part of the galls, being more suited to *bleach* than to *blacken* this, and every other part of them, no such effect, as that of rendering them black by making their supposed charcoal naked, or predominant, could be produced by any separation of the supposed excess of oxygene from a nitrate of iron.

Were it true, as M. Berthollet imagines, that the black colour of ink results exclusively from the two operations under consideration, viz. the reduction of iron to the state of a black oxide, and a partial combustion of the astringent vegetable matter which combines with it, a decoction of catechu, or of any one of several other vegetables, (which have been always found incapable of producing blackness with iron,) ought to be able to do it as efficaciously as the decoction of galls; since they are equally efficient in *abstracting oxygene* from the oxides of iron, (so as to bring it into the state of an Ethiops,) and

there is no reason to suppose that they are not equally susceptible of the sort of combustion which M. Berthollet imagines to be a consequence of that abstraction.

It is well known that we can deprive ink of its colour, by making it receive a stream of sulphuretted hydrogene gas, which must produce this effect only by causing an abstraction of the oxygene, to which the ink owed its blackness. And if this colourless ink be afterwards applied to paper, it will regain its oxygene, and its lost colour: and these facts seem to me incompatible with M. Berthollet's theory—sulphuretted hydrogene gas having never been found capable of *whitening* charcoal; and if their on of ink be already, as he supposes, in the *least oxidated* state, it cannot be made *white* by a farther abstraction of oxygene.

The theory which I am here forced to controvert, supposes causes which seem to me very insufficient, and it overlooks or disregards that which, to my apprehension, is the *true cause* of the effect under consideration. I mean the *peculiar nature* and *properties* of *the vegetable colouring matter* (of galls, &c.) which *specifically, though unaccountably*, produces the black colour of ink, with iron, and produces it more *intensely* at least with a *red*, than with the *black* oxide of that metal; if, indeed, it be possible to produce it with the latter. Why it does this, we may be able to explain, when, if ever, we shall dis-

cover the cause of those *peculiar affinities* of the several rays of light, by which they are severally made liable to be variously absorbed, transmitted, or reflected. But until such a discovery shall be made, it cannot be reasonably expected, that any person should execute a task, like that which has been unnecessarily assumed by M. Berthollet; it being no more incumbent on him to account for the production of a *black* colour, by the combination of iron with a decoction of galls, than for the production of a *blue*, by a combination of the same metal, with what is called Prussic acid; or to explain why the *colourless* basis of indigo, when united with a *full* portion of *colourless* oxygene, will copiously reflect, or transmit *blue* rays only; though with a smaller portion, it will reflect or transmit yellow as well as blue, so as to appear green; and with a portion still smaller, it will transmit the yellow, but no blue rays. The colour of logwood, extracted by pure water, is yellow; but it may be made to exhibit almost all possible variations of colour, by combining it with different bases or mordants; though it is, I believe, impossible to explain why any of these combinations should produce one colour in preference to another, especially as it is demonstrably the same *identical* colouring matter, which co-operates in producing all the affinities or attractions for the several rays of light which create these *varied* sensations of colour. Here, therefore, we may say with Pliny, (Lib. xxxvii, cap. 4,

"*Nec quærenda* in ista parte *naturæ ratio sed voluntas.*"

After these preliminary observations respecting the philosophy or theory of the black colour, as produced by the means under consideration, I shall proceed to a practical application of this theory to the subjects connected with it; beginning with that of

Ink.

Cicero (Tuscul. 5,) has given a copious statement of the important benefits resulting to mankind from the use of ink; but, probably they might, with more propriety, be ascribed to the *art* of writing, than to the *means* of exercising this art, of which ink is but one; though certainly it is not the least interesting among them.

The Latin name of ink, *atra*mentum, and the Greek name of *writing ink*, μέλανγραφικοῦ, strictly denote a *black* substance, and authorize us to conclude, that this was originally and exclusively the colour of the liquids employed for writing; though, afterwards, other coloured fluids were applied to the same purpose; and then to the names signifying *black* ink, or black matter,

* "Verum tamquam peculiare *nigro* colori esse censeo hoc *atramenti nomen*; quanquam pro pigmentis scriptoriis singulis, & diversi coloribus usurpatum sit." Caneparius. 191.

other words signifying *red*, *yellow*, &c. were *incongruously* united.*

It appears that the ancients had not, even in Pliny's time, become acquainted with our writing ink, or at least with the use of it as such, even though the black, produced by a combination of iron with the colouring matter of galls, oak, bark, &c. was frequently brought under their observation by shoe-makers, who gave this colour to their leather, as they do at present, and by the very same means; it seems probable, also, that galls were used to dye black with sulphate of iron, at the time when Pliny wrote his comprehensive work, for in his xvith book, chap. 6, after mentioning that all trees which produce acorns afford *galls*, Pliny adds, that those of the oak *hemeris* (which he had previously mentioned as bearing the largest acorns) were the best, and most suitable for *tanning leather;* that those of the broad-leaf'd oak were lighter, and less esteemed; but that it moreover produces a sort of black galls, which were more useful in dyeing;* and these he mentions again in the next chapter, and in the 4th chapter of his 20th book also; where, after describing the different sorts of galls, he adds that they all possess simi-

* "Sed gallam *Hemeris* optimam, & coriis perficiendis aptissimam: similem huic lati folia, sed leviorem, multoque minus probatam; fert et nigram: duo, enim genere sunt: *hæc tingendis utilior.*"

lar properties and *dye hair* or wool *black*, " Omnes capillos denigrant." That their colouring matter was combined with iron for this purpose, is not, so far as I recollect, expressly stated any where, but that Pliny was acquainted with the colour produced by such combination, is evident from the 11th chapter of his thirty-fourth book, in which, after mentioning the salt of copper (blue vitrol) as being frequently adulterated by that of iron (green vitriol, which the Greeks call *chalcanthon*,) he observes that this adulteration might be detected, by impregnating paper (that of the papyrus) with an infusion of gall nuts, and then smearing it over with a solution of the cuprous salt, which, if so adulterated, would produce a black colour. (" Deprehenditur & papyro galla prius macerato : *nigrescit* statim ærugine illita.") But the knowledge which the ancients possessed of the production of a black colour by a combination of iron with galls, oak bark, &c. is demonstrated by the use which they made of a solution of iron, to give that colour to tanned leather. This solution, or the sulphate of iron, dissolved by water for that purpose, was generally called by the name of " atramentum suto-

* This was afterwards used to signify bribery, and a person put upon his trial, and corruptly acquitted, was said to be " atramento sutorio absolutus," absolved by shoe-maker's black.

rium,"* *shoe-maker's black.* The Greeks and Romans, indeed, had incorrect notions of the nature of the sulphate of iron, and supposed it to bear some relation to copper, as the moderns did long after; an error which occasioned it to be commonly called, as it is even at this time, *copperas.* Thus Pliny tells us (lib. xxxiv. cap. 12) that the Greeks, in consequence of this supposed relation, had given the name of chalcanthum, to that substance which the Latins denominated atramentum sutorium; and after mentioning how, and the places where it was produced, its colour, transparent glossy appearance, &c. he adds, that being dissolved or diluted, it served the purpose of staining leather black.*

But, notwithstanding this knowledge of the black, produced by iron with galls and other matters, then employed for tanning skins, (among which were the pods of an Egyptian acacia, the cups of acorns, &c.) no application of this knowledge, for the production of *writing-ink*, appears to have taken place, when Pliny wrote his history; for in his thirty-fifth book, chap. 6, after mentioning the black pigment employed by painters, and describing it as being obtained like our lamp-black, by burning rosin or pitch in

* "Græci cognationem æris nomine fecerunt & atramento sutorio: *appellant* enim chalcanthum: nec ullius, æque mira natura est."——"*diluendo fit atramentum tingendis coriis.*" Plin. xxxiv. cap. 12.

places, which, he says, were constructed purposely to hinder the escape of smoke, he observes, that the *best* was obtained from torch wood, or pitch pine, though frequently adulterated by the soot collected in furnaces and bagnios; *and this he adds, is employed to write books.** He afterwards adverts to the wonderful nature of the cuttle fish and its ink, (of which, and of the use made of it to conceal themselves when in danger, he had given an account in the 29th chapter of his ninth book;) but observes, that no use was made of it as ink. "Mira in hoc sepiarum naturæ: *sed ex his non fit.*" In the same chapter, Pliny adds, that for the purpose of writing, the lamp black, or soot, was rendered much more useful by being mixed with gum, and for painting, by an admixture of glue—"perficiter librarium gummi, tectorium glutino admisto." And any person who will take the trouble of mixing lamp black with water, thickened a little by gum, may obtain an ink of no despicable quality in other respects, and with the advantage of being much less liable to decay by age, than the ink now in common use.

But though the Greeks and Romans in Pliny's time, were acquainted with no better writing ink, than that which I have just mentioned, the knowledge they had acquired of the colour

* "Laudatissimum eodem modo fit e *tedis*:" adulteratur fornacum, balinarumque *fuligine, quo ad volumina scribenda utuntur.*"

resulting from a combination of gall nuts, &c. with iron, would naturally lead them to employ the black so produced, as ink; and probably after doing so, they would find motives to induce them gradually to adopt its use; as, indeed, they appear to have done; though I cannot discover from Caneparius, who has written a volume on the subject, any evidence of the time when this substitution began; we may, however, infer from Sir Charles Blagden's communication to the Royal Society, (in the Phil. Trans. for 1787) that in the 9th century those who made it their business to copy manuscripts, used ink composed from iron and galls, though, probably, the use of it was not so general, as wholly to preclude that of *lamp black* or soot, in this way.* I shall, indeed, presently mention a composition of my own for ink, of which lamp black is a principal ingredient, and which may, probably, cause the latter to be hereafter employed in a similar way; at least for

* That the use of lamp black in making ink, was not wholly laid aside when Caneparius wrote, appears by the receipt which he has given at p. 176; for a *portable* ink, to consist of one pound of honey, the yolks of two eggs, half an ounce of gum arabic in powder, as much lamp black as would render the mixture sufficiently black. These were to be well beaten, and mixed in a mortar, so as to make an uniform and solid mass; of which, when wanted, a little was to be dissolved in water. Even at this time, the Boers at the Cape of Good Hope are said, I think by Mr. Barrow, to write with soot and brown sugar mixed in water; and I have often seen such ink employed by farmers in North America.

purposes which may require a most durable and almost *indestructible* ink. Of the writing inks most generally used in the beginning of the 17th century, when the work of Caneparius was printed at Venice, he gives an account, between page 170 and 179; and they appear to have consisted principally of galls, sulphate of iron, water, and gum, in different proportions, to which some persons added the bark of mountain ash, or the ripe berries of the privet; and others, the rinds, or peelings, of pomegranates; and these last he strongly commends, as contributing very much both to the *lustre* and *blackness* of the ink; and I have sometimes been disposed to adopt this opinion; but, probably, the good effects which I had occasionally observed from this addition, may have been manifested only when, from a defect, or want of the galls, the proportion of iron would have been too great without the pomegranate peels, which, indeed, will alone produce a good ink, with sulphate of iron.*

The best proportions among those suggested by Caneparius, seem to have been half a pound of sulphate of iron to one pound of galls, with a quarter of a pound of pomegranate rinds, and about as much gum; but even ink so made, would have been more lasting, if not blacker, with a few ounces more of galls. He afterwards

* Having noticed some printed receipts, for making ink with pomegranate peels and sulphate of *copper, instead of iron,* I prepared such an ink, but the colour, as I had expected, was merely an olive brown; *not black.*

highly commends the addition of a little white sugar to ink. Some persons, he tells us, employed wine instead of water, which rendered their ink less liable to be spoiled by freezing; and to obviate this more effectually, Caneparius proposes an addition of brandy to the ink. He observes, at page 172, that some *ink-makers used the black liquor of the cuttle fish*, in addition to the other matters. ("Admiscen tatrum liquorem sepiæ piscis marini," &c.*)

* This wonderful genus, (*sepia*, or *cuttlefish*) consists of eight species, of which, some inhabiting the ocean between the tropics, are very large, and provided with a terrible apparatus of arms or holders, beset with *suckers*, by which they seize and hold their prey. Each of the eight arms of the sepia octopus is said to be sometimes eight or nine fathoms in length, and strong enough to seize a boat and draw it under water; a circumstance which induces the boatmen of India, always to carry hatchets to cut off these arms, if applied to their boat. All the species are provided with a dark-coloured fluid, (which in some is quite black) secreted by a particular glandular organ, and contained in a membranous purse destined for its reception. This fluid they emit to obscure the water, when it is wanted to favour their own escape from danger, and, perhaps also, when, by concealing their approach, it may enable them with greater facility to seize their prey. This liquid consists of a mass of extremely minute carbonaceous particles, intermixed with an animal gelatine or glue, and capable of being so widely spread, that an ounce of it will suffice to darken several thousand ounces of water. The sepia officinalis, or most common species of this genus, and the sepia loligo, (calimary, or sea sleve) appear to have been eaten by the ancients, as they now are by the Italians, and the Lacedemonian *black broth*, is supposed to have been made by boiling them whole together with their ink bag, the mucilage contained in

At page 177, Caneparius directs the composition of an ink powder, by mixing and grinding

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it being well-tasted. Indeed, the sepia tunicata, inhabiting the Pacific Ocean, and frequently weighing one hundred and fifty pounds, is, according to good accounts, convertible to very wholesome and palateable food; and even the dangerous sepia octopus is said to be eatable, though it has been supposed to possess an electric or galvanic power, like that of the torpedo, or of the gymnotus electricus, and to be thereby assisted in subduing its prey; as the sensations of persons seized, or touched by the arms of this animal, are stated to have been much more *painful* than any which mere mechanical violence of equal force could produce. When dissected this animal is said to be highly luminous.

Having frequently heard and read, that the coloured liquor of the cuttle had been formerly employed as ink, I procured one of the sepia officinalis, and made trials of its ink, by writing with it on paper, and applying it to stain calico; upon the latter I could not fix it, so as to bear a single washing; but I have now before me, some writing performed with this matter, which bears date the 28th. of June, 1796, and which seems to be as black as it was at first, though the strokes of the pen are not uniformly black, the carbonaceous particles seeming not to have been equally dispersed through the gelatinous fluid; and this latter being liable to putrify, the black liquor in its *natural* state could not be long preserved for the purposes of ink; though the carbonaceous matter might easily be separated from the animal mucilage, and mixed with a solution of gum arabic, which would not be liable to putrefaction

Caneparius supposes, p. 193, that Dioscorides had, besides indigo, intended to describe a *black* pigment obtained from India, to which Paulus Ægineta alluded in his seventh book, under the name of Melan Indicum, or Indian ink. As indigo had then been brought from Asia to Greece and Rome, it seems not unlikely that the pigment which we call Indian or Chinese

together galls, with about one-third of their weight of sulphate of iron, and one-fifth of gum, and the same quantity of alum ;—(which last is, I believe, now properly omitted in these compositions) and in the following page, he describes an ink for staining linen, &c. which was prepared by putting iron filings and powdered galls into the strongest vinegar, and placing them

ink, might also have come to the knowledge of Dioscorides. But, however this might have been, it seems to be now ascertained, and generally believed, that our Chinese ink is obtained from the black liquor of some of the species of sepia. I could adduce many authorities in support of this belief, but the following will suffice, viz. Cuvier, in the fifth volume of his Leçons d'Anatomie comparée, p. 262, after describing the structure of the cuttle fish, and the nature of its ink, observes, that the latter is not by much so black, in the common cuttle fish, as it is in that species which the French called *poulpe* (*sepia* octopus) and he adds that " L'éncre de la Chine n'est bien certainement pas autre chose, que la production de quelque espéce de *poulpe* de ce pays la. Ce seroit donc, vainement qu'on chercheroit a l'imiter, par des mélanges artificiels. L'analyse Chimique y a reconnu, un carbone tres-divisé, mêlé á un gluten animal."

The following is from Paul Hermann's Cynosura, tom i. part 17, p. 11, viz. " Sepia piscis est qui habet succum nigerrimum instar atramenti, quem chinenses cum *brodio orizæ* vel alterius leguminis inspissant, et in universum orbem transmittunt, sub nomine atrimenti Chinensis."

And in confirmation of this, M. Chaptal states, that " Dans les pays chauds, en Italie et dans le midi de la France, on emploie la liqueur de la *seche* aux memes usages et avec le même succès que la meilleure encre de la Chine." Chimie appl. aux arts, tom. iv. p. 300.

over the fire, until so much of the metal had been dissolved, as would produce the required blackness. The fluid part of the mixture was then separated by straining, and thickened by gum. This composition, though differing in regard to the method of preparing it, resembles the prosubstantive black, from acetate of iron and galls, commonly employed at this time by calico printers.

At page 179, Caneparius describes a method of restoring the blackness of writings, which were become illegible by age, and this was by an infusion of galls in white wine, which he afterwards subjected to an unnecessary distillation, and then applied the liquor to the *faded letters*, by a sponge, or a little cotton, which, he says, rendered them as distinctly visible as when first written. Prussian blue was not then known, and, therefore, the application of its colouring matter for this purpose (as recommended by Sir Charles Blagden) was impossible; and that being the case, the means suggested by Caneparius (excepting the distillation) were the best which could have been employed; and seem to indicate, that he must have justly imputed the loss of blackness in writing ink to the decay of its *vegetable*, and not of its *metallic* part.

Though two centuries have nearly elapsed since the publication of Caneparius's work, no improvement of much importance seems to have

been since made in the composition of writing ink. The late Dr. Lewis, indeed, bestowed particular attention upon this subject; and his Philosophical Commerce of Arts contains some accurate, as well as judicious, observations relating to it; especially in regard to the use of logwood, with which Caneparius does not seem to have been acquainted, at least as an ingredient in the composition of ink.

The desired blackness of colour, as well as its durability, in this composition, depend entirely upon the proportions in which the vegetable colouring matter and the oxide of iron are united; though, among the different recipes which have been published, the variations are so great as to manifest either culpable ignorance in the authors of them, or great diversities in the quality of the galls, from which the colouring matter is generally directed to be obtained: in some of these recipes, equal parts of galls and sulphate of iron are directed; and in others, six times as much in weight of the former as of the latter. Certainly galls from different species of oak, and from different countries, vary much in their comparative proportions of colouring matter; and even among those which are commonly called the best Aleppo galls, one pound of the heavy blue, or unperforated galls, will commonly prove equal to one pound and one half of the *white*, from which the insect has escaped, and which,

from their having been longer upon the tree, with large perforated or open cavities, exposed to the weather, and particularly to rain, will have suffered a considerable loss of colouring matter. These two sorts of galls, as commonly imported, are mixed together in nearly equal portions, and are then called *galls in sorts*, which are to be understood as meant by me, when the contrary is not expressed.

Of such galls, I think, from the results of numerous experiments, that three pounds will afford the most suitable proportion of colouring matter, for one pound of sulphate of iron, when the former is intended to be obtained exclusively from galls; and when logwood is to be employed conjointly with the latter, the galls may be diminished at the rate of one half of the weight of logwood. In regard to the proportion of galls to that of sulphate of iron, my opinion accords with that of Lewis, who found that three pounds of the former to one of the latter, commonly produced the best and most lasting ink. Ribaucourt, indeed, thinks two pounds of galls sufficient for one of sulphate of iron, and certainly with this proportion, an ink may be produced sufficiently black; but not so durable, as it would be with a larger proportion of vegetable colouring matter.

In regard to the use of logwood, Chaptal does not consider it as being capable of adding any

thing to the blackness of ink, made with galls and sulphate of iron, in suitable proportions; but he thinks, that it contributes to hinder a precipitation of the colouring matter, and that the ink, of which it is a component part, is, by its use, rendered more smooth, or *marrow-like*, (moëlleux) and the black in appearance more soft; and that the strokes made with it by the pen are more clean. To me, however, logwood has always seemed to give additional body, or fulness, to the colour of ink, though it cannot be supposed to render it more lasting; for, by many experiments, I have found that neither on paper, or parchment, any more than on linen, or cotton, or, indeed, wool, was the black resulting from a combination of logwood and iron, of equal durability with that from galls and iron. And it may, therefore, be best in making ink, to employ, as Chaptal advises, only half as much in weight of logwood as of galls. He thinks also, that the addition of sulphate of copper, in the proportion of one ounce to every fifteen ounces of galls, produces a good effect; that the bluish tint which accompanies ink when first made, even in the most suitable proportions, (until sufficient oxygene has been absorbed) will be sooner overcome by this addition, and that it will also contribute to render the ink more lasting.

But of this last effect I am very far from being convinced; because it has been fully ascertained,

by experiments which I have repeatedly made, that the colouring matter of logwood cannot be made so durable, upon either paper, wool, silk, linen, or cotton, when united to an *oxide of copper*, as it is with that of *iron;* and though, by producing a *dark blue* with copper, it may improve the shade of black resulting from the iron and galls, this blue, by fading sooner than the black, which logwood produces with iron, (when no copper is present,) must render the ink so much the less durable. I have here supposed the effect of copper to result exclusively from its union with the colouring matter of logwood, for with that of galls it can produce neither blue nor black.

M. Chaptal would reject the use of sugar in making ink, as being completely useless; for to him it did not seem even to render the ink more glossy or shining; though such an effect has always been manifest to my apprehension. He found no benefit by employing either vinegar, wine, or beer, instead of water, as a vehicle of the colouring matter of ink; indeed, he was persuaded, that beer did harm, by increasing the disposition of ink made with it, to become mouldy.

M. Chaptal concludes from his numerous experiments in regard to writing ink,* that the best ingredients and proportions for composing it, are

* See his Chimie appliquée aux Arts, tom. iv.

the following, viz. Two parts of galls in sorts, bruised, and one part of logwood chipped; these are to be boiled in twenty-five times their weight of water, for the space of two hours, adding a little water, from time to time, according to the evaporation. The decoction so made, he says, will commonly mark from 3 to $3\frac{1}{2}$ degrees upon the hydrometer of Beaumé, equal to about 1022 of the common standard. At the same time, a solution of gum arabic is to be made with warm water, until the latter will dissolve no more of the former. This solution will mark 14 or 15 degrees, equal to about 1110. A solution of calcined sulphate of iron is also to be made, and concentrated so that it will mark 10 degrees, equal to about 1071. And to this, as much sulphate of copper is to be added as will be equal to $\frac{1}{13}$th part of the galls employed to make the decoction. The several matters being so prepared, six measures of the decoction are to be mixed with four measures of the solution of gum, and to this mixture, from three to four measures of the metallic solution are to be added, by a little at a time, mixing the several matters each time, by shaking. Ink so made will, he says, form no sediment: and he estimates the proportions of solid matters contained in it to be 500 parts of gum, 462 parts of the extract of galls and logwood, and 481 parts of metallic oxides.

But though the hydrometer may enable those

who will employ it, to obviate or correct the uncertainties resulting from the difference of quality in galls, some persons may wish to avoid the trouble of doing so, and choose rather to incur the risk of some little defect in the ink they may prepare, and for their satisfaction, therefore, I will mention the following, as being generally the most suitable proportions for composing the best and most lasting writing ink, viz.

Take of good Aleppo galls, in sorts, coarsely powdered, twelve ounces, and of chipped logwood six ounces; boil these in five quarts of soft water two hours, and strain off the decoction whilst hot; then put to the residuum as much boiling water as, when properly stirred, strained, and added to the former, will suffice to make the whole of the decoction equal to one gallon; add to this five ounces of sulphate of iron, with the same quantity of gum arabic, and two ounces of good dry muscovada sugar; let these be all dissolved, and well mixed by stirring.

I do not consider a calcination of the sulphate of iron, which Chaptal, Proust, and some others, have recommended, as of much importance; for though the ink may be thereby made to attain its *utmost* degree of blackness, almost immediately, the strong disposition which ink has to absorb oxygene from the atmosphere until saturated therewith, will enable it, without such cal-

cination, to attain an equal degree of blackness, in a day or two, according to the temperature of the air, if the latter be allowed free access to it. I have omitted the sulphate of copper, for the reasons lately mentioned; and if any portion of that metal were deemed beneficial, I should prefer verdigrise to the sulphate, the latter containing a much larger proportion of acid, than even the sulphate of iron, and being, therefore, more likely to render the ink corrosive.

Some persons have recommended the addition of indigo to ink; but, unless it be previously dissolved by sulphuric acid, it will be found to subside, even though very finely powdered; and, if so dissolved, this increased portion of acid will render the ink much more corrosive; and after all, the blue afforded by this combination, (as was formerly noticed in regard to the sulphate of indigo,) will not prove very durable.

Gum is highly useful to retard the separation, and subsidence of its black part, or compound of colouring matter and iron, previous to its application to paper, as well as to hinder it from spreading and penetrating too far into the latter, when applied to it.

As the acid part of galls is extracted more readily than the other soluble parts, especially when the water employed for that purpose is cold, and as ink, which, along with colouring matter, con-

tains more than the ordinary proportion of this acid, is the least disposed to produce a sediment (for the reasons lately assigned,) some persons have recommended the making of it by *a cold* infusion of galls. But when this is done, the galls must be employed in a much greater proportion; and, even with this additional expence, there will be cause to fear that ink so obtained, may not prove so durable as other ink containing a full proportion of the less soluble, but more STABLE, part of the colouring matter of galls. It is, therefore, with good reason, that Lewis, Chaptal, and others, have recommended *boiling* to extract the *whole* of the soluble matter contained in galls; especially as oxygene will be absorbed during the ebullition, and this absorption will contribute to give the ink its full degree of blackness so much the more speedily.

Ink, in which the colouring matter of logwood bears a large proportion, will be made red by applying muriatic acid to it; this redness, however, will soon disappear, and the former blackness be restored, partly at least in consequence of the volatility of the acid.

It does not appear that any considerable advantage is gained by substituting any of the other acids for the sulphuric, to dissolve iron for making ink; though the case is different in regard to dyeing and calico-printing.

I have already observed, that an excess of sul-

phate of iron produces ink of a *blueish* tint, which, if the excess be great, will, at no remote period, become yellow; probably, because the affinity of the metallic oxide for oxygene, not being counteracted by a sufficient portion of vegetable matter, the latter will gradually suffer a decomposition from the excess of oxygene absorbed, and at length the oxidated iron alone will remain. A similar effect will, indeed, take place, after a long course of years, even when there is no disproportion of iron; but it will be retarded by increasing the proportion of galls beyond that which produces the blackest colour; and, indeed, by such an increase as to make the ink incline considerably, from what is deemed a good black, towards a brownish purple.

But, unfortunately, that ink in which the proportion of galls is greatest, is the most disposed to become mouldy; a defect which it is difficult, if not impossible to hinder, in any considerable degree, so long as ink retains the mucilaginous part of the galls, which water always extracts along with the colouring matter. It has, indeed, been found, that by keeping a saturated infusion, or decoction of galls, six or eight months, more or less, according to the temperature of the atmosphere, and carefully removing the mouldy pellicle, when it forms on the surface, from time to time, the mucilage will at length be wholly separated from the remaining part of the infusion or decoction, and no subsequent pro-

duction of mouldiness will then take place therein; and if it be afterwards passed through a fine strainer, and mixed with a suitable proportion of sulphate of iron and of gum arabic, an ink may be formed, which will be exempted from the defect of mouldiness. It was, probably, in this way that the ink, sold in France under the name of *encre de Guyot*, was prepared; and Dr. Tarry has, in the Ann. de Chimie, tom. 74, given a receipe for preparing an ink on this principle. It must, however, be observed, that by this method of separating the mucilage from the colouring matter of the galls, a considerable portion of the latter will be also taken away and lost; and there is room to suspect, that the remainder, by its having been kept so long in a fluid state, will have suffered some degree of deterioration, tending to render the colour of the ink, when made with it, less durable. And, therefore, knowing that the mucilaginous part of the galls does not combine with the iron and colouring matter in the formation of ink, I thought it might be practicable and advantageous to separate the former from the latter, by adding just enough of *caustic* potash to the ink, to neutralize the sulphuric acid, and throw down the black compound of iron and vegetable colouring matter; and after separating this last by a filtre, or fine strainer, re-dissolving, converting it again to ink with sulphuric acid, sufficiently diluted, or with *distilled* vinegar, avoiding that which had not been

distilled, as it would restore other mucilage almost as hurtful as that which this process might separate. And having produced an ink in this way, I found it quite unobjectionable, and free from all disposition to become mouldy.

Newman formerly recommended the adding of cloves to ink, in order to counteract its disposition to mouldiness: and the late Dr. Black adopted this recommendation, advising only, that the cloves should be powdered, and rubbed in a mortar with the mucilage of gum arabic, to render their essential oil miscible with the ink; and by this expedient he supposed that an ink might be obtained, which would be but little, if at all, subject to the defect in question. I did not, however, in repeating this experiment, find any considerable benefit from cloves, employed in this way, and therefore substituted camphire, which seemed to answer better, though it appeared to give the ink a blueish tint; but I have been since convinced, that neither these, nor any other means, will completely obviate the mouldiness in question, so long as ink retains the *mucilaginous* part of galls *in a liquid state.*

M. Chaptal observes,* that since the oxygenated muriatic acid has been found capable of discharging the colour of common writing ink, both from parchment and paper, without injuring

* Chimie appliquée aux arts, tom. iv. p. 244.

their texture, it has been fraudulently employed to efface particular parts or words of deeds, contracts, and other writings, for which others have been substituted, leaving the signatures untouched; and that, in consequence of these frauds, the commercial part of society, as well as governments, became solicitous for the discovery of some composition, which might be employed instead of common writing ink, without its defects, and therefore, (being then minister of the interior of France, and possessed of great chemical science) he, as might be expected, occupied himself particularly with that subject; and he states, that up to the then present time, the composition which had been found most useful for this purpose, consisted of a solution of glue in water, with which a sufficient portion of lamp-black, and a little sea-salt were intimately mixed, by rubbing them together on marble. This composition was made sufficiently thin (by water) to flow readily from the pen; and he describes it as being "*d'un trés bon usage*;" and capable of resisting the action, not merely of cold, but of boiling, water; and also of acids, alkalies, and spirit of wine; and attended with no inconvenience, but that of abrasion, by being rubbed. ("Elle n'a que l'inconvenient de s'estomper par le frottement.")

Though I have never made trial of this composition, I can readily believe M. Chaptal's ac-

count of its good properties; but I must observe, that it differs from the ink commonly used when Pliny wrote in nothing but the addition of sea-salt, (for which, as being less disposed to deliquate, I should think either salt-petre or sulphate of potash might be advantageously substituted) and in the employment of *glue* instead of gum arabic, (which Pliny recommends) to give the composition sufficient tenacity and consistency. Indeed, Pliny, as I lately mentioned, directs glue to be employed with lamp-black instead of gum, when the atramentum or black mixture was intended to be applied as a pigment internally to the walls, &c. of houses. I have, indeed, found that when lamp-black has been incorporated with common ink, by first rubbing the former in a mortar with a mucilage of gum arabic, the writing done with it could not be rendered invisible by the application of muriatic acid; and, doubtless, such an addition of lamp-black would hinder the letters from ever becoming illegible by age, at least within any length of time which the paper and parchment could be expected to last. But ink made with this addition would require to be frequently shaken or stirred, as the lamp-black would otherwise be apt to separate and subside. Glue could not be advantageously employed with any ink containing tannin, for obvious reasons.

As all inks in which the colouring matter is mixed

with an aqueous menstruum or vehicle, are liable to suffer injury by wetting, I resolved to make trial of the essential oil or spirit of turpentine, and to incorporate with it, as intimately as possible, a sufficient portion of finely-powdered lamp-black; and having done so, I obtained an ink which proved to be sufficiently black, and flowed from the pen readily, and with a remarkably smooth and homogeneal effect. I have, indeed, now before me, several pieces of writing, for which this composition was employed (dated at Kew, in September, 1799) and the strokes of the pen, though fine, are as distinct and even as possible. Strong nitric and muriatic acids have been applied to different parts of the writing, without impairing the colour in the slightest degree; nor did boiling water cause the letters to run or spread. The most concentrated sulphuric acid, or oil of vitriol, being dropped upon the writing, and suffered to remain several days, was found to have nearly destroyed the paper, but not the writing. And I cannot conceive any purpose, depending upon the fixity, durability, and indestructibility of ink, which may not be answered by this composition; there being, as I am persuaded, no chemical agent, nor any length of time which can efface its impressions, without destroying the paper or parchment on which they are made.

In some parts of the East Indies, a permanent

writing ink is formed, by dissolving the brownish black liquid contained in the oriental marking nuts, (semecarpus anacardium), mentioned at p. 308 of my first volume. The solution is to be made by an alkaline lixivium, and afterwards neutralized by vinegar.

There are some few instances of inks said to be produced by vegetable colouring matters upon the basis of alumine, instead of iron, one of these, first mentioned by Ray, and afterwards by Linnæus, is from the poisonous berries of the actea spicata, or common black-berried herb Christopher. Linnæus also mentions the fruit of the empetrum procumbens, as affording another such ink. I believe, however, that neither of these can be lasting.

Barham, in his Hortus Americanus, mentions the pods of the mimosa juliflora, (improperly called poponax in Jamaica) as affording a good ink on a similar basis. He says, " they soak some of the pods all night in water, then mix a little alum with it, and boil it to a due thickness, which makes a very fine black and strong ink," and he adds, that he had often made and written with it. Reflecting, however, upon the family and genus to which this tree belongs, I am persuaded that the black which it affords must be produced by iron, which might very easily be dissolved, partly by the astringent vegetable matter, and partly by the acid part of the alum contained in the infusion,

while the latter underwent the *boiling* which is prescribed, if performed, as it doubtless must have been, in an iron vessel; and this, probably, is the fact also, in regard to the natural ink, which the inspissated juice of the old trees of the fagus castanea, Lin. is said to afford. The inspissation or evaporation of this being, doubtless, performed also in iron vessels; though Crell has supposed, that the juice of this tree naturally contains iron; but certainly it cannot contain it in any proportion sufficient to produce such an effect.

After this account of the various kinds of writing ink, (which I have made the more copious, because the subject is generally interesting) I shall proceed to the application of

The Black Dye upon Wool and Woollen Cloth.

Among the Greeks and Romans, *black was confined* to their *mourning* garments, and to those in which the priests sacrificed to the *infernal* gods; for to the *celestial*, this office was performed in *purple*, and to *Ceres* in *white*.* But in modern times, and among the more civilized nations of Europe, the use of black is much more extensive, it being worn at *all times*, by certain orders and

* See Bishop Potter's Antiquities of Greece, vol. i. p. 225, and ii. 196.—Cicero (in Vatinium) asks, " Quis unquam cœnavit *atratus?* Who ever went to a supper dressed in black?"

professions; and by *all* orders and professions, at *some* times, as in public and private mournings; and, moreover, hats, and some particular garments, are commonly worn of that colour at almost all times; and it is, therefore, perhaps, the most important of all the colours given by dyeing.

I have already mentioned, that among the three primitive, or simple, colours, blue is that which approaches nearest to black, and that the deepest and most perfect black may be produced on woollen cloth, merely by the accumulation, or condensation, of a sufficient quantity of indigo blue, even of that which is rendered the most lively and bright, by being combined with sulphuric acid. I have mentioned also, the method practised, more particularly by the famous dyers of the name of Gobelin, of dyeing black without either galls, logwood, or iron, in any state or form, merely by superadding to the woad or indigo blue, a *red* colour from madder upon the aluminous basis, and a yellow from weld, upon the same basis: indeed, the dyeing of wool or cloth *black*, without previously giving it a dark blue ground from woad, was prohibited in France, by the regulations promulgated by the minister Colbert, excepting only coarse stuffs of little value, for which it was lawful to substitute a dark-coloured ground from the rinds of walnuts, or the bark of the roots of walnut-trees: and the regulations anterior to those sanctioned by Col-

bert, had required a madder *red* to *be superadded to the blue* ground, as an indispensable part of the black dye.

Black cloths which, in addition to the blue, had obtained the madder red, were called *mathered* blacks in this country; and the act of the 23rd of his present Majesty, cap. xv. entitled "An Act for rendering more effectual the provisions contained in an act of the 13th year of King George the First, for preventing frauds and abuses in the dyeing trade," declares, that if any persons shall thereafter "dye, or cause to be dyed, any cloths, bays, or other woollen goods of any kind, or sort whatsoever, as, or for, mather (madder) blacks, the same not being dyed throughout, in the *first place with woad and indigo*, every such person shall forfeit and pay the respective penalties" therein mentioned; and that "if any person shall dye, or caused to be dyed, any woollen cloth, as, or for, *woaded* black, the same not being woaded throughout, every such person shall, for every such offence, forfeit, and pay for every piece of such cloth, the sum of two shillings per yard." This act also directed, that all *mathered* black truly dyed, should "be marked with a *red* rose and a *blue* rose," (to signify the blue and red dyes which it had received) and that all "truly woaded black throughout," should be "marked with a *blue* rose only;" and the application of these marks to cloths not truly dyed, according to this act, was made

punishable by a fine of four pounds for each of these marks. This act is still in force, though, probably, not well observed or executed.

Hellot, in assigning the reason why one, at least, of these grounds is required, and why it is made unlawful to dye cloth *directly* from *white* to *black*, observes, (chap. xx.) that to produce this colour from galls and sulphate of iron *alone*, so much of the latter would be necessary to saturate ("surmonter") the former, or as he expresses it, to produce an *ink in the wool*, that its fibres would be thereby rendered harsh and brittle.*—(" Il

* It has been long and generally believed, that cloths dyed black were more easily torn, or, according to the common expression, rendered more *rotten* than those dyed of other colours; and this defect was at first commonly ascribed to the acid part of the sulphate of iron, employed in the black dye; but afterwards, from observing the injury done to linen, &c. by iron moulds, the blame was transferred to the *oxide*, or, as it was then called, the *earth* of iron. Accordingly, the Dijon Academicians, in treating of this defect, state the following observation :—" On sait aujourdhui qui ce n'est *ni la Causticité de l'acide*, ni la chaleur du bain, qui brulent, mais que *ces sont les parties terreuses du Fer, qui y restent et qui en se precipitants sur l'étoffe la rendent cassante.*" Elémens de Chimie, &c. tom. ii. p. 293. To this I may add the following, by M. le Pileur d'Apligny, viz. " M. Hellot a fort bien observé qu'un drap teint en noir, sans pied de bleu, ni de racinage, demande une plus grande quantite de cuperose, qui rend l'Etoffe assante ; et j'ai remarqué aussi, que lorsqu'on fait dissoudre de la rouille de fer, dans du Vinaigre pour le jaune,

faudroit une grande quantité de cuperose, qui non seulment rudit l'etoffe mais que la rend cassante," &c.) He thinks, however, and with reason, that where galls and sulphate of iron are intended to form a part of the black colour, the madder red may be spared, if the very *deep blue*, required by the French regulations, and called "*bleu pers*, has been faithfully dyed. And, indeed, broad-cloth so dyed, may be made to acquire a black in every respect unexceptionable, by boiling it two hours in a decoction previously made, from about one-seventh of its weight of galls and as much chipped logwood, afterwards passing it for another two hours through a solution of one-tenth of its weight of sulphate of iron, and keeping the

ou le noir, des Toiles Peintes, la Toile est *sujette a se dêchirer, dans les endroits ou ces couleurs sont appliquées,* lorsqu'on n'a pas eu l'attention d'écumer la dissolution, pour enlever la Terre la plus grossiere. *C'est a cette Terre qu'il faut attribuer le Défaut des Etoffes teintes en noir, de se casser facilement, et non pas à l'acidité du sel de vitriol,* ni a aucune cause, qui les brule, suivant l'opinion du Vulgaire."—L'art de la Teinture de Fils et des Etoffes de Cotton.

That there is some foundation for the supposed greater rottenness of black cloths, than of those with other colours, I am disposed to admit; but, doubtless, in many instances, the defect is principally occasioned by the practice of applying the black dye to cloths which have previously undergone and been injured by certain dyeing operations, intended to produce other colours, which, having proved faulty, were fit only to be made black.

solution at a scalding heat only. Most dyers content themselves with using a smaller proportion of galls, and making up for this deficiency by increasing the quantity of logwood, and by adding also a portion of sumach.*

For coarser cloths, and cheap woollen stuffs, the blue ground from woad, or indigo, is now commonly omitted, and its place badly supplied by one from logwood, and either sulphate of copper, or verdigrise; or the latter is dissolved with the sulphate of iron, to convert a part of the colouring matter of logwood into a blue dye. But the employment of *copper in any form with logwood, as a dye for wool, or woollen stuffs, ought to be, and in fact is, prohibited*, by the act of the twenty-third year of his present Majesty, lately mentioned; which declares, that any person who shall "use, or cause to be used, any logwood, or logwood liquor, in dyeing *blue*, any cloths, bays, or other woollen goods of any kind, or sort soever, shall, for every such offence, forfeit and pay the sum of

* Some dyers think they obtain a perfect black with more ease and certainty, by boiling deep blue broad-cloth two hours in a decoction of galls, then passing it through a warm solution of sulphate of iron, then through a hot decoction of logwood, then a second time through the solution of iron, and again, if necessary, through the logwood liquor; and repeating these alternate applications until the desired colour shall have been produced.

twenty pounds, for every piece of such cloth, &c. in the dyeing of which, any logwood, or logwood liquor, shall have been made use of, as aforesaid." This prohibition, which is, I fear, rarely, if ever, now enforced, relates merely to the use of logwood in dyeing *blue;* and for this colour it is always employed with some preparation of *copper*, which, as a basis for the colouring matter of logwood, can produce none but a blue, and one which is a very fugitive colour, especially on wool and woollen cloth. The using, therefore, of either verdigrise, or sulphate of copper, even in the dyeing of *black* with logwood, ought to be considered as an infringement of the act; it can produce nothing like a black or blue colour with galls, sumach, or any other vegetable matter, commonly employed for this purpose, and its only effect, and, indeed, the only purpose which it is intended to answer, is that of producing a logwood blue, by uniting, as it does exclusively, with the colouring matter of this wood, and by the very dark blue resulting from that combination, rendering the black at first more *intense*, though it afterwards changes to a rusty brownish colour, much sooner than it would have done if no preparation of copper had been employed, and if the colouring matter of the logwood had been applied to the cloth, in conjunction with an iron basis alone; it having been demonstrated, by experiments which I have made repeatedly, that the

logwood colour is much more permanently fixed upon wool, silk, linen, and cotton, by the latter basis, than by any preparation of copper.

Pœrner, indeed, pretends, that equal parts of sulphate of copper and logwood, will dye upon woollen cloth a perfect black, capable of sufficiently resisting the impressions of the air, &c. He admits, however, that the use of so great a proportion of sulphate of copper ought to be avoided, on account of its being more corrosive than the sulphate of iron; and for this reason he proposes to employ only one part of the former to two or three of the latter, with a suitable quantity of logwood; which, he says, will not injure the cloth, and will produce a perfect black without the aid of a blue ground. I have, however, tried sulphate of copper with logwood, not only in equal, but in various other portions, without having been able to produce any thing like a perfect black, even in appearance, and much less a black sufficiently permanent. With sulphate of iron and logwood, indeed it is not difficult to produce a full and deep black; but it certainly will not prove so lasting as the black with sulphate of iron and galls, or sumach, either alone, or with a moderate proportion of logwood; which last, certainly improves the appearance of the black, dyed from galls and iron, by rendering it more intense, glossy, and soft, or *velouté*, as it is expressed by the French.

All black cloths, for the dyeing of which a large proportion of logwood has been employed, may be *reddened* by the application of muriatic acid. Lime-water obstructs the production of a black by logwood and sulphate of iron, though a small proportion of potash favours its production.

Hats are dyed *without* a blue ground from indigo, by galls, logwood, and sulphate of iron, and for these, as well as for woollen cloths, the vegetable colouring matters are applied *first*, and the mordant, or sulphate of iron, *afterwards*, contrary to the practice observed in dyeing other colours. A peculiarity which has been ascribed to a belief, that the sulphate of iron, if first applied to cloth, not impregnated with the vegetable colouring matter, would act more injuriously upon its fibres, than it does by a subsequent application; though the experiments which I have made do not convince me that this belief is well founded in any case, and more especially where the cloth has been previously dyed blue with indigo.

Probably, the practice has arisen, though without a proper knowledge of the motive from the very little affinity which subsists between the iron contained in the sulphate of that metal and the fibres of wool, until they have imbibed a portion of vegetable matter. There is, as I stated in my first volume, a very marked attraction between the oxide of iron and the fibres of linen or

cotton; but this oxide is much more strongly attracted by the vegetable colouring matter, than by the fibres of wool, and, therefore, it has been found most advantageous to impregnate the latter with this colouring matter first, and afterwards to apply the solution of iron; and even when this has been done, it is found very difficult to render *white* cloth *black*, by the mere application of galls and sulphate of iron, unless these applications are made repeatedly; though it may be done readily where the cloth has previously received a blue ground; or where the effect of the galls and iron is assisted by adding to it the purple, blue, or violet colour, of logwood. Lewis, in his Philosophical Commerce of Arts, observes, that "vitriol, (meaning sulphate of iron) and galls, in whatever proportions they are used, produced no other than browns;" and that "logwood is the material which adds blackness to the vitriol and gall brown;" but that "on blue cloth, a black may be dyed by the vitriol and galls only;" though, even in this case, as he says, the logwood deepens the colour. This observation is, however, only true, in regard to the *single* application of galls and sulphate of iron; which, whether the iron or the galls be first applied, and the other superadded, will at most only produce a brownish black on white cloth; manifestly, because the latter does not at *once* imbibe enough of the iron to answer the purpose; but by renewed applications of iron and

galls alternately, a good and lasting black may be obtained, without either a blue ground, or the co-operation of logwood.

About the year 1753, Bergman strongly recommended a method of dyeing cloth black, after it had received a blue ground, by first boiling it for two hours in a bath with one pound of sulphate of iron and half a pound of tartar for six pounds of cloth, (taking care that the tartar should be all dissolved before the sulphate was added,) and, after having rinced the cloth, dyeing it in a separate bath, with a sufficient portion of the arbutus uva ursi, or bear-berry ; though this, without the blue ground, would not, as Lewis has observed, afford a black colour, unless assisted by logwood.

Berthollet (tom. i. p. 126) quotes Mr. Delaval, as having stated, (in his Experimental Enquiry, &c.) that by a simple dissolution of iron in a decoction of gall-nuts, he had not only produced the blackest and most durable ink, but that, having immersed therein both silk and woollen stuffs, without adding any acid, he had dyed them of the *deepest and most permanent black*. All this, however, must have been subsequent, by several years, to my communication upon this subject to the Royal Society, of which he was a member ; and if he did not rely solely upon that communication, but actually performed what is thus stated, he must have been fortunate in dissolving so *exactly* the proportion of iron, necessary to produce these *excel-*

lent effects; an operation which, after I had at first accidentally succeeded in performing it, I found liable to so many failures, from the dificulty of ascertaining, at any time, how much of the metal had been actually dissolved, that I have long ceased to expect that it can ever be adopted with advantage by dyers.*

I have mentioned, at p. 305 of my first volume, that a fine lasting black, without iron or any other basis might be dyed upon blue cloth, from a species of lichen, called *rags*, or stone rag in the North of England, (the lichenoides pulmonium reticulatam vulgare marginibus peltiferis, of Dillenius); and if this could be readily and copiously obtained it would, probably, deserve to be preferred to madder and weld for rendering blue cloth black; and, indeed, I have found, that the brownish yellow which alder bark affords upon the aluminous basis, may, for this purpose, be advantageously substituted for that of weld.

* The best, and, perhaps, only method of doing this, would be first to ascertain, as nearly as possible, the quantity of iron in its metallic state, which will produce the best effects when *totally* dissolved by, or with the soluble part of a given quantity of galls; but it would be highly inconvenient, and, in several respects, disadvantageous, to wait long enough for this *complete* dissolution of the iron, unless it were first brought into the state of *iron filings*; which, for general use in dyeing black, would be attended with more trouble and expence, than any advantage to be expected from this change seems likely to be compensate.

Of the Application of the Black Dye to Silk.

The fibres of silk not being organized like those of wool, do not so readily admit the black dye as the latter. Dr. Lewis (in his Philosophical Commerce of Arts) observes, that "woollen and silk are both dyed of a permanent deep black, but with this difference, that what the woollen dyer effects by three or four dippings of the cloth, in his dyeing liquor, the silk dyer scarcely obtains from twenty or thirty dips."

Though raw silk imbibes the black dye with as much facility as that which has been deprived of its gum, yet, when dyed, the black appears less intense and less fixed in the former than in the latter; and it is, therefore, made previously to undergo the usual boiling, with one-fourth or one-fifth its weight of soap, during three or four hours: by this operation, indeed, silk often loses nearly one-fourth of its weight, but this loss is more than compensated by that which it gains from the black dye.

As the affinity of silk with the soluble parts of galls is greater than with the iron contained in a solution of the sulphate of that metal, it is thought most advantageous to begin by first applying the former; and for this purpose about one-half as much in weight of Aleppo galls as of the silk to be dyed, is boiled in a suitable proportion of water, three or four hours, after

which, the decoction having been left to settle, the fluid part is separated from the sediment, and the silk maceratedtherein twenty-fourhours, more or less, according as the impregnation is intended to be more or less copious; and being afterwards dried and slightly rinced, the silk is immersed in a solution of the sulphate of iron moderately warmed, and kept therein with the usual management, until the colouring matter of the galls has nearly saturated itself with the oxide of iron; after which it should be rinced and immersed, &c. in a warm decoction of logwood; and having there imbibed as much of the colouring matter as may be disposed to unite with it, the silk is to be again immersed in a solution of iron, then rinced, and again transferred to the decoction of galls, repeating these alternate immersions, &c. until the desired colour shall have been produced. —Some dyers think it expedient, or at least beneficial, to employ, for dyeing silk black, about one-sixteenth of its weight of verdigrise, which may be either mixed with the solution of sulphate of iron, or with the decoction of logwood. Iron dissolved by the pyroligneous or acetous acid, is, in some respects, preferable to the sulphate of that metal.

By repeated macerations in the decoction of galls, and drying it between each of them, silk may be made to imbibe an increased proportion of their soluble matter, and having done this,

it will attract an increased proportion of the oxide of iron, and thus acquire nearly a fourth part more in weight than it originally possessed, before its gummy covering had been separated by the boiling with soap. But the colour produced by this excess or superfluity of the black dye, is not commonly so perfect, or so permanently fixed, as it is when no such excess has been employed.

In addition to other means, and in order to improve their effects, silk dyers often provide themselves with what is called a black vat, (or *tonne au noir*, by the French) composed of ingredients, differing considerably in different places; of which, however, the principal are vinegar, sour beer or cider, and oatmeal in water, with alder-bark, sumach, oak-bark, and sometimes galls; to which old iron hoops, or other thin pieces or minute divisions of that metal are added, and left to undergo a gradual dissolution, by the joint action of the acetous acid, and of that contained in the acerb vegetable matters just mentioned, or others possessing similar properties. The longer these mixtures have been made, the better they are found to answer the purpose for which they are intended. At Genoa (which has long been celebrated for its black dye) and other places on the continent, such vats have been made to subsist for ages, being replenished, from time to time, by additions of the several ingredients, (some of

them, probably, useless), as fast as those formerly supplied may appear to have been exhausted.

The black dyed at Genoa upon velvet, and also upon a thinner sort of woven silk, to which I applied strong muriatic acid, appeared to have been produced with some, though not a large proportion of, logwood, and not to have received any blue ground from indigo or woad; and, indeed, this ground, though some persons have recommended it, is, I believe, now rarely given any where in the dyeing of silk black.

The Chinese are said to improve their black dye upon silk, by passing it, when dyed, through a bath containing at the rate of one pound of starch, with half as much of the oil of linseed, or of rape, or hemp-seed, for every five or six quarts of water.

M. Berthollet (tom. i. p. 16.) has described a process, communicated to the Academy of Lyons, in 1776, for dyeing silk, by M. d'Anglês; but, on account of its length, I beg leave to refer my readers to that description, should they desire to know more of it.

Of the Application of the Black Dye generally, to Cotton or Linen, either woven or spun.

The late Dr. Lewis, after mentioning the difficulty which attends the application of the black dye to silk, adds, that " the dyer of linen and cotton thread, however he prolongs the operation, or repeats the dippings, is unable to communicate

to the thread a blackness that shall endure wearing." That there was some foundation for this observation at the time when it was made by Dr. Lewis, I am disposed to admit; though it must have resulted chiefly from the *improper methods* employed to communicate the black colour to these substances; for certainly the oxide of iron has more affinity, and unites itself more readily and permanently, with the fibres of linen and cotton, as is daily observed, in what are called iron-moulds, and in the buff colours produced by it, than it does with the fibres of either wool or silk; and, indeed, more permanently than any other basis is known to do; and there being a marked attraction between this oxide and the colouring matter of galls, sumach, &c. the black produced by these means, might well be expected to prove as durable on linen or cotton as on wool; and probably the only reason (in addition to the improper methods of dyeing) why it has not been thought so, is, that linen and cotton are subjected to occasional washings with soap, which is rarely applied to wool and silk when dyed black. Hitherto the dyers of cotton and linen have been accustomed, like those of wool and silk, to apply the vegetable part of the black dye *first*, and the solution of iron afterwards; thereby inverting the order observed in regard to other adjective colours, but with much less reason for doing so than the dyers of wool and silk have; at least, if the

results of my experiments are not very fallacious.

It is notorious that the calico printers, when they wish to produce any adjective colour, by the aid of iron or its oxide, as a basis, invariably begin by applying the basis (commonly the acetate, or the pyrolignite of iron) separately to the calico, superadding the vegetable colouring matter afterwards; excepting only in those cases where a less permanent prosubstantive black or other colour is applied, for which the basis or mordant is previously mixed and combined with the vegetable colouring matter. And it is well known that the black and other colours given by calico printers, from sumach, madder, weld, quercitron bark, &c. upon an iron basis, applied first and *separately*, are much more lasting than the same colours produced in a different manner by the ordinary dyers. And it has not, I believe, been found that the colours produced by calico printers, upon an iron basis, separately and previously applied, had injured the texture, or shortened the wearing of the calico, any more than colours given by the aluminous basis, at least when the acetate or pyrolignite of iron had been duly prepared and applied; though it must be admitted that iron, in a certain state of oxidation, if accumulated in or upon the fibres of linen or cotton, will render them brittle by impairing their flexibility. Of this fact I need only give the following instance or illustration: Having more than twenty years ago prepared

two solutions, one of the green sulphate, and the other of the nitrate of iron, and having thickened them by suitable additions of powdered gum arabic, I marked an equal number of shirts and pocket handkerchiefs with each; and leaving them to undergo the usual course of washing and wearing, I observed, from time to time, the comparative effects of these different preparations of iron. The letters which had been marked with the sulphate, soon became of an even, smooth, pale yellow colour, which did not sensibly diminish, either in quantity or appearance, by any subsequent washing, nor did the parts or fibres of the linen to which this sulphate was applied appear less flexible, or ultimately prove to be in the slightest degree less durable than the other parts generally. But the effect of the nitrate of iron was very different, as the letters produced by it were of a brownish orange colour, with a rough unequal appearance, and the fibres of the linen, impregnated with the oxide, were so manifestly rigid, that I was not much surprized at finding holes produced, instead of the marks or letters, after a few washings. It appeared in this case, that the nitric acid had not only produced a much higher degree of oxidation, in the iron dissolved by it, but had combined with a larger proportion of the metal; so that, in addition to the greater oxidation, there was an accumulation of the oxide, where it had been applied to form

the letters or marks; and the corroding influence of this accumulation was, doubtless, augmented by farther and continued absorptions of oxygene from the atmosphere.

From the results of this and other experiments, I have long been convinced, that a nitrate of iron cannot be directly applied to the fibres of linen or cotton, without producing injurious effects, unless it be much diluted, and very minutely divided; or unless it be mixed with a carbonate of potash, or some other matter suited to obviate the rigidity and corrosive influence which it would otherwise occasion. It has, indeed, long been a practice among calico printers, to dissolve iron by aquafortis, and afterwards mix the solution with a decoction of galls, to produce a prosubstantive black for topical application. By which mixture, the nitrate of iron is deprived of a part of its oxygene, and the oxide so much divided as to hinder, in a great degree at least, the accumulation and consequent rigidity before mentioned. Though there has often been some reason to think, that even this application was not innocent, in regard to the fibres of the calico blackened by it.

There is, however, no cause to fear this sort of injury from a *direct* application of the acetate, or the pyrolignite of iron, in the usual ways, as a basis for the colouring matter of galls, sumach, &c.; and I am confident, from the results of many experiments, that being so applied, (in the

manner, and with the precautions mentioned between pages 312 and 319 of my first volume) there can be no difficulty, afterwards, in producing a *full and permanent black*, by dyeing the linen or cotton, which has received this basis, with a suitable portion of galls, with or without an addition of sumach, and even without the co-operation of a blue ground, (from indigo) which is commonly thought necessary, at least for the finer and more costly cotton, or linen goods, intended to be made black: when linen and cotton have been so dyed, the colours may be more strongly fixed, by passing them through a weak solution of blue.

It may be proper, after having suggested what I consider as a decided improvement in the mode of applying the black dye to linen or cotton, that I should notice the methods most generally practised and approved for imparting that colour to these substances. M. le Pileur d'Apligny (in his "Art de la Teinture des fils et étoffes de Coton,") describes the process most esteemed and practised for this purpose at Rouen; and by his description it appears that cotton yarn, and linen thread, are first dyed blue with indigo, and afterwards galled; employing a quarter of a pound of gall-nuts for each pound of yarn or thread; they are afterwards macerated, and worked by hands, three several times, in the liquor of the black vat, drying them between each of these macerations; and being finally well rinced, they are dyed with a

quantity of galls and alder bark, sufficient to saturate the iron applied by the liquor of the black vat. To soften the black so produced, the thread and yarn are commonly passed through a remnant of weld liquor, and afterwards through a bath of warm water with which linseed oil has been mixed and well stirred; employing for this purpose at the rate of one ounce of oil for each pound of the dyed thread or yarn. This employment of linseed oil, gives a soft glossy appearance to the black dyed upon linen and cotton, and it also renders the colour more intense and durable; and it should always be so employed, when linens and cottons have been dyed black, in the manner which I have just recommended, i. e. that of first applying the acetate or pyrolignite of iron, and afterwards the colouring matter of galls and sumach. But care must be taken not to withdraw the linen or cotton yarn from the mixture of oil with water, until, by suitable management, the oil has been equally dispersed and applied to the dyed substance. For cotton-velvets, indeed, and piece goods, it will be advisable first to apply the oil generally, over the surface, by a *brush*, and afterwards favour the spreading and absorption of it equally by passing them through warm water. Goods which have been dyed with a pyrolignite of iron, must be afterwards well aired, lest they should retain the unpleasant smell which accompanies that acid.

M. Vitalis (see Manuel du Teinturier sur fil et sur Coton filé, p. 127,) strongly recommends the following process for dyeing black upon thread and cotton yarn, viz. Let them be first galled, employing from two to three ounces of galls to each pound of thread or yarn, and then macerated in a warm pyrolignite of iron, marking from five to six degrees upon the aréomètre of Beaumé, equal to about 1·040 of the common standard. After this impregnation, they are returned again to the decoction of galls, and afterwards to the pyrolignite of iron, replenishing each of them, from time to time, until the proper colour shall have been produced; which, in his estimation, will not require more than five ounces of galls, and sixteen ounces of the pyrolignite of iron, (of the strength just mentioned) for each pound of thread or yarn: after which the latter are to be rinced, dried, and impregnated with linseed or olive oil, in the manner lately described.

The most common method of dyeing cotton black, at Manchester, has, at least until very lately, been that of first making it imbibe the colouring matter of galls, or sumach, and then saturating this colouring matter with the liquor of the black vat; then passing it through a decoction of logwood with verdigrise; and repeating these impregnations until the desired colour was produced, but always drying the cotton between each. Now, however, the pyrolignite of iron is frequently substituted for the liquor of the black

vat, but not, as I believe, applied previously to the vegetable colouring matter.

M. Hermbstaedt, of Berlin, has lately recommended (in the Biblioth. Phys. Œconomique, an. xiv. No. 2,) a method of dyeing black upon cotton, by applying to the latter a mordant consisting of the oxides of iron and copper, precipitated from solutions of the sulphates of those metals, and heated so as to make them absorb a maximum of oxygene; after which, they are to be dissolved in the pyroligneous acid; the cotton being impregnated with this mordant, is to be dyed with galls, sumach, logwood, &c. But having already stated that the oxide of copper can be of no use in producing a black colour, otherwise than by combining with the colouring matter of logwood, and that the *blue*, which it forms by that combination, is more fugitive than the *black* which logwood forms with the oxide of iron, when no copper is employed at the same time, it can hardly be necessary for me to observe, that M. Hermbstaedt's mordant is faulty, in as much of it as relates to the oxide of copper, of which the seeming good effect cannot be lasting.

Of the application of the Black Dye, topically and prosubstantively to Calico, &c.

I have already, in several parts of this work, and particularly at p. 352 and 3 of my first volume, mentioned the method employed in the East Indies to produce black figures, or stains, upon calico, which has imbibed the colouring matter of

the terminalia chebula, partially or topically, by applying to *it* a solution of iron by the acetous acid; and I have in other parts, and especially between pages 375 and 379, of the same volume, described the opposite method employed by European calico printers, of communicating similar figures or stains to calico, by *first* printing or applying the solution of iron (by the acetous or pyroligneous acid) to the calico, and afterwards superadding the vegetable colouring matter, (commonly from madder or sumach,) by a dyeing process. It, therefore, only remains for me to offer some observations respecting the application which it is often highly convenient to make in calico printing, of the matters affording writing ink prosubstantively, or in a state of combination, instead of either of the *other* methods of applying them *separately*.

Forty years ago, some calico printers, as I was then informed, knew that the colouring matter of galls, produced a more permanent *prosubstantive*, or, as they termed it, *chemical* black, when combined with iron dissolved by *aquafortis*, than it did by any other preparation of that metal with which they were acquainted. No one, however, then appeared to suspect the cause of this increased permanency, though it will now be readily understood to have resulted from the greater degree of oxygenation which the iron had acquired from this acid; but, unfortunately, it also

acquired properties which were sometimes found to have injured the texture of the calico stained by it; especially when the nitrate of iron had been employed in such proportions as were suited in other respects to produce the best and most durable colour; and when the composition, after its application, was, as is usual, dried in places *artificially heated*. The use, however, of this composition, has subsisted until the present time; and the following is, I believe, the most approved method of preparing it, viz.

Take single aquafortis, or nitric acid of the specific gravity of about 1·260, and let it dissolve iron until saturated therewith; and having at the same time made a decoction of the best galls, of which each gallon should contain the colouring matter of two pounds of the nuts, mix these together, in the proportion of eight ounces of the solution, or nitrate of iron, to each gallon of the decoction, and let the mixture be properly thickened, according to the method in which it is intended to be employed, or applied; if by the pencil, with gum tragacanth. The mixture, if made with ten, or even twelve ounces of the nitrate of iron, instead of eight, will work more pleasantly, by affording neater and better defined impressions, and with some improvement of the colours; but there would then be danger of its hurting or weakening the fibres of the calico. The black produced by the mixture just described, is suffi-

ciently lasting for all the ordinary uses of printed calicoes, and unobjectionable in regard to its appearance; and were it always *innocent* in regard to the texture of the cloth, there would be no great need to seek for any other. I ought to observe, that instead of water, some persons think it better to employ vinegar to extract the colouring matter of galls.

A composition for this purpose, is not unfrequently made, by adding to each gallon of the decoction of galls, twelve ounces of the sulphate of iron, (instead of the nitrate of that metal,) and boiling the mixture, for an hour, or an hour and one half, by which it will gain a considerable portion of oxygene, and with it a deeper, and more permanent black colour. This composition has been, and I think justly, deemed harmless, in regard to the fibres of the cotton; though when thickened with flower, for printing by the block, it does not unite therewith permanently; but in a day or two separates, or *parts*, in the language of the printers, so as not to be capable of adhering equally and properly to the block. By calcining the sulphate of iron, previous to its mixture with the decoction of galls, the subsequent boiling, except for a few minutes, would be rendered unnecessary, and the iron would become even more oxygenated than by the boiling. Some persons employ a portion of the colouring matter of logwood, conjointly with that of the galls, which

renders the black more intense at first; but this effect, or *addition* of colour, will not be so permanent, as the black resulting from the combination of iron with the soluble part of galls.

Some years ago, I purchased of a calico printer, possessing great knowledge of the principles and practice of his art, the secret of a composition which he had employed with success, as a prosubstantive black, and which, as far as I can judge from experiments upon a small scale, deserved the high commendations which he bestowed upon it; and though I have never obtained the smallest pecuniary advantage from this purchase, in any way, I will here *give* the full benefit of it to the public. The following was his recipe, with some abreviations of language, viz.

Take two pounds of the best mixed galls in powder, and boil them in one gallon of vinegar, until their soluble part is extracted, or dissolved; then strain off the clear decoction, and add to the residuum of the galls as much water as will be equal to the vinegar evaporated in boiling; stir them a little, and after allowing the powdered galls time to subside, strain off the clear liquor, and mix it with the former decoction, adding to the mixture six ounces of sulphate of iron; and this being dissolved, put to it six ounces more of sulphate of iron, after it has been previously mixed with, and dissolved by half of its weight of single aquafortis; let this be stirred, and equally dispersed through the mixture, which is to be thickened

by dissolving therein a sufficient quantity of gum tragacanth, (of which a very small proportion will suffice.) Calico after being printed or pencilled with this mixture, should, when the latter is sufficiently dried, be washed in lime water, to remove the gum and superfluous colour, and then either streamed or well rinced in clear water.

This composition has not been found to weaken, or injure, the texture of calico printed or pencilled with it, and the colour is thought unobjectionable in regard to its blackness and durability.

I ought here to mention, that when sulphate of iron is mixed with aquafortis, the latter undergoes a decomposition; the oxygene of the nitric acid combining with the iron, and raising it to a much higher degree of oxidation; and that the result of these operations is the production of a fluid which has the consistence, and smooth appearance of oil, and which, (though the name may not be quite unexceptionable,) I will call a nitro-sulphate of iron. I have, however, been induced to believe, from several trials, that a better prosubstantive black than either of those here mentioned, or indeed than any other within my knowledge, may be formed, by taking a decoction, containing in each gallon the soluble matter of two pounds of the best galls in sorts, and, when cold, adding to it for each gallon twelve ounces of sulphate of iron, which had been previously mixed with half

its weight of single aquafortis, (of which one wine pint should weigh about twenty ounces) and, by the decomposition just described, converted to the nitro sulphate of iron just mentioned. By thus employing twelve ounces of sulphate of iron, oxygenated by nitric acid, instead of six ounces of the latter, with six ounces of the green sulphate in its ordinary state, an improvement in the colour seems, by my experiments, to have been invariably produced, and without any corroding or hurtful action upon the fibres of the cotton.

It having appeared to me, some years ago, to be highly expedient that the *comparative* degrees of stability and permanency, of the black colours, which galls, myrobalans, sumach, and logwood, were capable of affording with iron, should be ascertained, and knowing that each of them, with *certain* proportions of this metal, was capable of affording a blacker and more lasting colour than with any other less suitable proportion, I projected and executed the following experiments, as being eminently adapted to manifest the truths which appeared so desirable.

I prepared half a pint of a decoction of galls, which was made to contain the soluble matter of two ounces of the powdered nuts in sorts, and having ascertained the specific gravity of this decoction, I prepared a like quantity, and of the like specific gravity, of the decoctions of su-

mach, logwood, the fruit of the terminalia chebula of Retz, (or yellow myrobalans of the shops) and also of the ash-coloured pear-shaped fruit, of another species of myrobalans, then recently imported from India, and which I take to be the terminalia belerica of Roxburgh.* At the same time I prepared what I thought a sufficient quantity of the nitro-sulphate of iron, recently described, by mixing six ounces of the green sulphate, with three ounces of aquafortis ; and having properly thickened the several decoctions with equal portions of gum tragacanth, I, with a suitable glass measure, put into each of them two drachms of the nitro-sulphate of iron, and having mixed it equally, I applied a little of the five several decoctions, or mixtures, to *one* end of a long strip of white calico, taking five strips for this purpose, and appropriating one of them exclusively to each of the several decoctions or mixtures. Each of these *first* applications was followed by twenty-four others, all made in succession, but only after one scruple of the nitro-sulphate of iron had been added to each of the several decoctions, and well mixed with it previously to any *new* application.

* They could not have been the fruit of the phyllanthus emblica, as some persons then supposed, because the latter is described by Louriero as being *three* celled and *two* seeded, whilst the stoney shell of the fruit under consideration, had but *one* cavity or cell, with a *single* kernel.

In this way, thirty scruples of the nitro-sulphate of iron had been added at twenty-five different times, to each of the five mixtures, when the last application of each to the calico was made, and each strip, when dried, and properly cleansed with lime water, &c. exhibited the colour or effect of twenty-five several applications, all with *different* and *increasing* proportions of the nitro-sulphate of iron. And as the *first* application to each of the five strips contained only about one-fourth of that portion of iron which I supposed requisite to produce the best colour, so the *last* contained double that portion, by the subsequent additions, joined to the continued abstractions of vegetable colouring matter, which these several applications required; and I was, therefore, certain, that though the first application would contain too little iron, and the last too much, one at least of the intermediate ones, in each of the five strips, would contain the exact proportion required to produce the best and most durable black, which that particular vegetable was capable of producing with the nitro-sulphate of iron; (and probably the best which it would produce with any other preparation of that metal,) and that by comparing together the best of the several strips, I should be able to ascertain the desired truths. These several strips having been washed with soap and water, were fastened, by small tacks, each to a separate board, so that the *same* surface,

fully *extended*, was constantly exposed to the sun and air, on the south side of my garden-wall, against which the several boards were placed during three summer months, in such manner that the portion of sun-shine upon each, was as equal as I could make it.

Recollecting when this experiment was devised that it might also be highly useful to ascertain whether the sulphate of *copper*, so frequently recommended and employed for dyeing black with *logwood*, was capable of producing with that wood, a colour as lasting as the black which it produces with *iron*, I took an equal quantity of the same decoction of logwood, with which the nitro-sulphate of iron was mixed in the preceding experiment, and having thickened it also with gum tragacanth, I mixed with it two drachms of powdered sulphate of copper, and applied some of the mixture to a *sixth* strip of cotton, to which were added twenty-four other applications, each containing an addition of one scruple of powdered sulphate of copper more than the preceding, and this being dried, cleansed, and washed exactly like the other five strips, was in like manner exposed by the side of one of them, at and during the very same time.

The colours of the several strips under consideration, being examined after having been thus exposed, during three summer months, those near the middle of each strip were in general, found to

be comparatively the most perfect, and to have suffered the least by this exposure. There were in each strip three or four applications adjoining each other, which, though made with some difference in the proportions of metal, had produced effects *equally good*; and this fact seemed to prove, that some small latitude or variation in that respect might be admitted, without harm. Of the mixtures with iron, a considerable part of those in which that metal had been used too sparingly, were found to have produced colours which, though only brownish purples, or purplish blacks, had not greatly faded; whilst those in which the iron was in the greatest excess, were become rusty browns, but little better than iron moulds. Generally, however, the colours upon each strip were deficient either in blackness or durability, according to the degrees in which they severally *receded*, on each side, *from* the more *central* and perfect blacks. Those with some excess of iron had at first appeared more black than those with an excess of vegetable matter; but the latter proved more durable.

When I came to compare with each other, the best colours in each of the first five strips, I found those from galls, and from the fruit of the terminalia chebula, or yellow myrobolans, to be considerably better than any of the others, and *so equally good*, that I knew not which to prefer. They were, indeed, but slightly injured by the exposure which they had undergone. Next to

these were the best of the colours produced from sumach, and next after these, those from what I suppose to have been the fruit of the terminalia belerica; the difference, however, was great between the latter and the colours from the *yellow myrobalans;* which last, therefore, and the galls produced upon the same tree, ought, as I think, to be exclusively imported. The least permanent of the colours produced with iron, were those afforded by the logwood; but even these were considerably more durable than the colours which the same wood had afforded with the sulphate of copper; which, by several comparative trials, I have found to be more lasting upon *cotton* than upon *wool:* and it is in consequence of the results of these several experiments, that I have endeavoured to discourage the use of sulphate of copper, or verdigris with logwood, in the black dye; and especially when it is to be applied to woollen cloth.

From the experiments, of which I have just given an account, as well as from many others, I infer that twelve ounces of the sulphate of iron, converted into a nitro-sulphate, as before described, contain such a portion of iron as will prove most efficacious and suitable for the colouring matter of from two pounds and one half to three pounds of the best Aleppo galls in sorts, when they are employed to compose a prosubstantive black colour.

In addition to this account of the uses and effects of galls, sumach, myrobolans, and logwood, it may be proper that I should notice some few of the other vegetable matters which are capable of being employed with iron for similar purposes.

One of these was mentioned by the late John Rheinhold Forster, in a communication which he made to the Royal Society, in 1772, and which was published in the sixty-second volume of their Transactions; of which the following is an extract, viz.

"The inhabitants of Mexico have but lately learnt of the inhabitants of California, the art of dyeing the deepest and most lasting black that ever was yet known. They call the plant they employ for that purpose cascalote; it is arboreous, with small leaves and yellow flowers; its growth is slower than that of oak: it is the least corrosive of all the known substances employed in dyeing, and strikes the deepest black; so that for instance, it penetrates a hat, to such a degree, that the very rags of it are thoroughly black. The leaves of this cascalote are similar to those of the husioke, another plant likewise used for dyeing black; but of an inferior quality. The latitude of California lets us hope, that the country near the Mississipi, or one of the Floridas contains this cascalote, the acquisition of which would be of infinite use in our manufactures."

This account is defective by not affording any

intimation respecting the basis or mordant with which (if there be any) this vegetable was employed to produce these effects, or respecting the name under which it may have been known to Botanists, or the genus to which it might be referred. I conclude, however, from many circumstances, that it belongs to the comprehensive genus of mimosa (which contains many species capable of dyeing black with iron,) and in fact that it must be the mimosa juliflora lately mentioned, at p. 448, as affording an excellent ink: it seems not to have been indigenous at Jamaica; but now grows there in considerable plenty, whence it might perhaps be advantageously imported to this country.

Michaux (p. 243) mentions the andromeda arborea, or sorrel tree, as bearing beautiful panicles of white flowers, with acid leaves, which are preferred by the inhabitants of the *Tenesee* country to sumach for dyeing black. Loureiro (tom. i. p. 186) mentions the leaves of the crassula pinnata as being employed in Cochinchina for the same purpose; "ad tingendas telas colore nigro usurpantur:" and at p. 573, he informs us, that a similar use is there made of the leaves of the juglans catappa.

Having lately mentioned the bark of the acer-rubrum, or scarlet flowering maple of North America, as affording with iron, the *purest, most perfect, and durable, black*, I need only express

my hope that it may speedily be brought into general use here for dyeing that colour.

The bark, leaves, and fruit of the anacardium occidentale, or cashew-nut tree, (casuvium of the French Botanists) afford copiously a colouring matter, which with iron produces ink and dyes black. The laurus borbonia, diospyros virginiana, morinda royoc, and many other vegetables, might be mentioned as producing similar effects; but I think it proper here to finish this chapter, and with it my present Work. Whether I shall hereafter make any addition to it, will depend on the prolongation of a life, of which the sixty-ninth year is now passing away; and upon other events, which, notwithstanding my inclination for this subject, may, in a great degree, withdraw my attention from it.

THE END.

GENERAL INDEX.

N. B. A line between the numbers of two pages which are not consecutive, indicates that the subject is continued from the former to the latter, through the intermediate pages.

THE END.

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